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FLOWER CREEK BASIN
FLOWER CREEK DAM
LIBBY, MONTANA
MT-1458

PREPARED FOR:

HONORABLE THOMAS L. JUDGE
GOVERNOR, STATE OF MONTANA

PACIFIC POWER & LIGHT COMPANY
(OWNER AND OPERATOR)

PREPARED BY:

MORRISON - MAIERLE, INC.
CONSULTING ENGINEERS
APRIL 1980

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PHASE I INSPECTION REPORT

NATIONAL DAM SAFETY PROGRAM

FLOWER CREEK BASIN

FLOWER CREEK DAM

LIBBY, MONTANA

MT-1458

MONTANA
RODGER C.
FOSTER
3654 E
REGISTERED
PROFESSIONAL ENGINEER

Rodger C Foster

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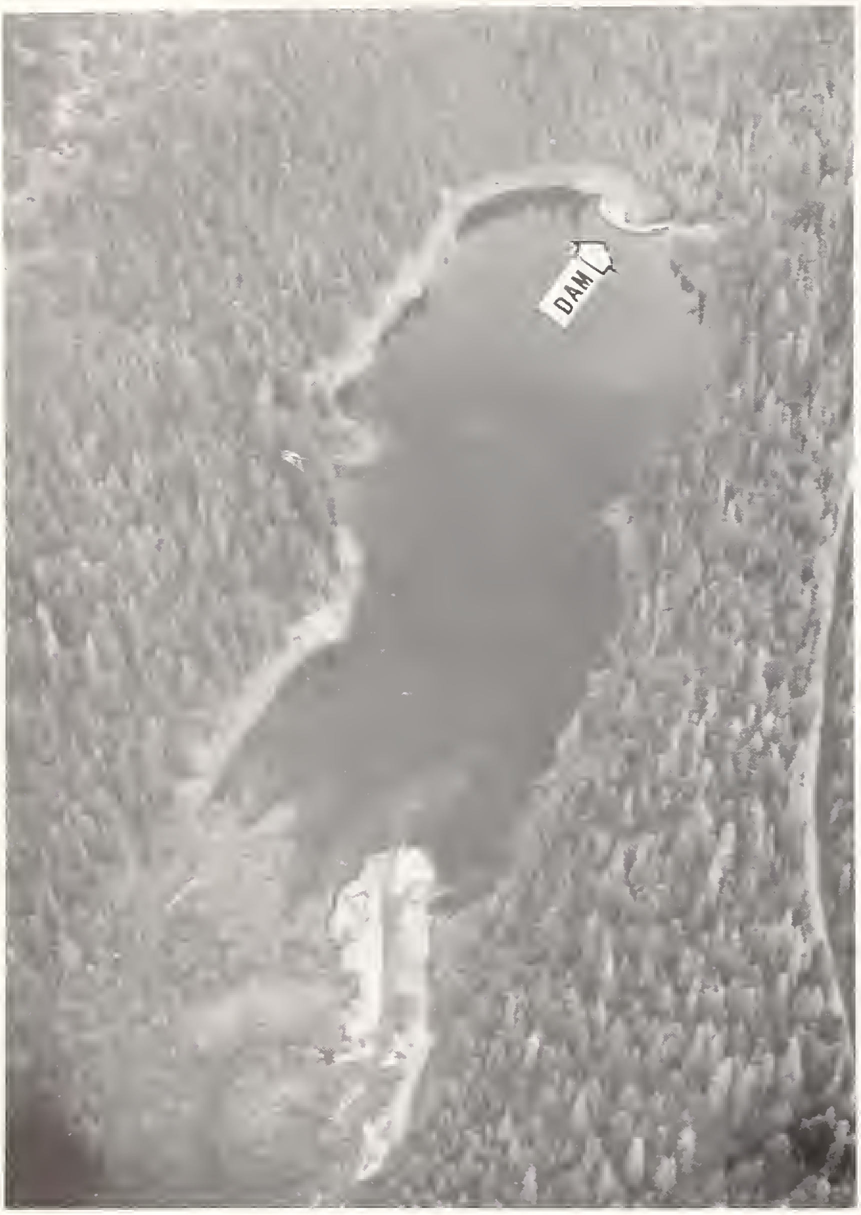
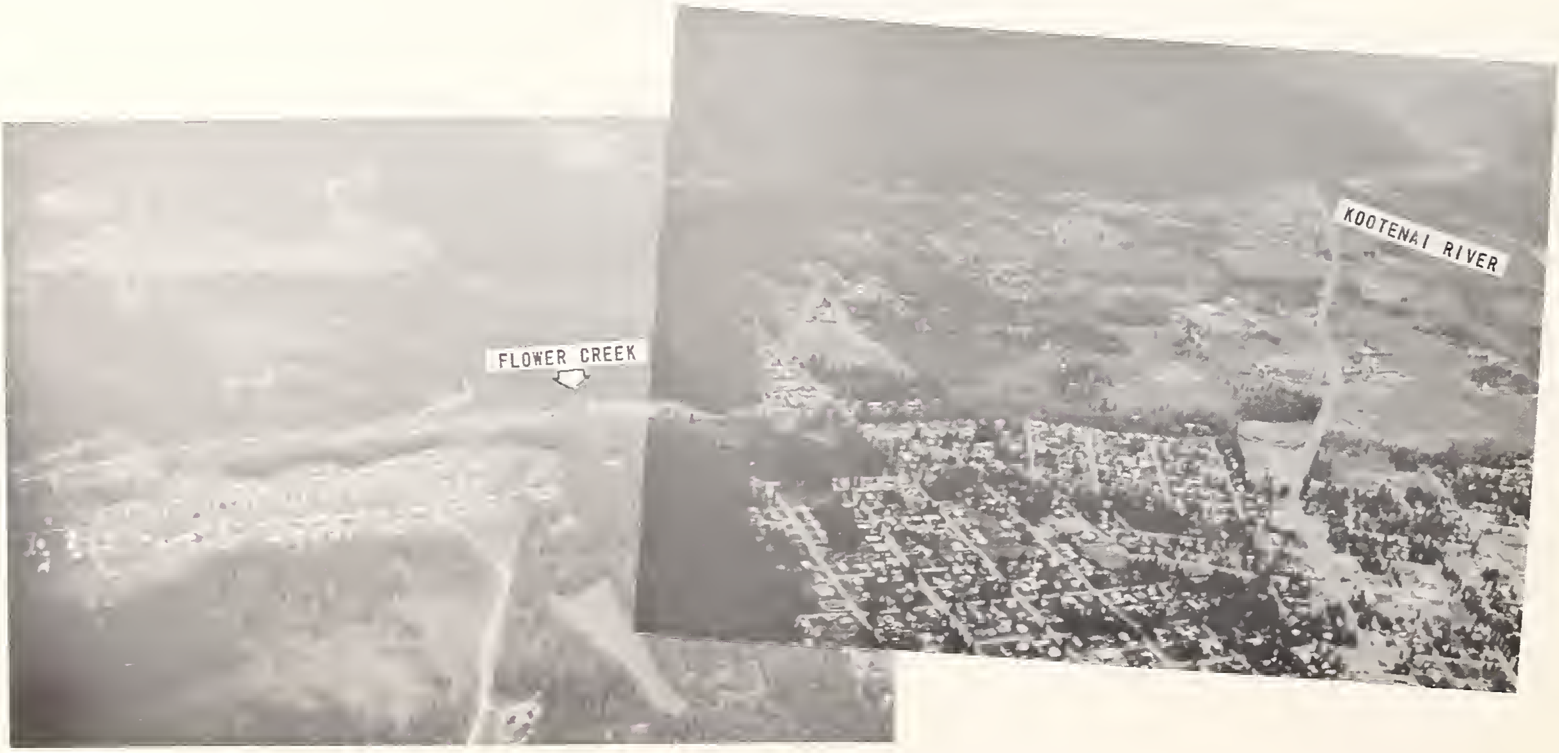


PHOTO 1 AERIAL VIEW OF FLOWER CREEK RESERVOIR



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EXECUTIVE SUMMARY

FLOWER CREEK DAM

INTRODUCTION

Morrison-Maierle, Inc. under contract with the Montana Department of Natural Resources and Conservation, who are under contract with Seattle District, U.S. Army Corps of Engineers, inspected Flower Creek Dam on September 14, 1978 under the authority of Public Law 92-367 and in accordance with the "Recommended Guidelines For Safety Inspection of Dams" prepared by the U.S. Department of the Army, Office of the Chief of Engineers. Flower Creek Dam is located in northwestern Montana on Flower Creek about three miles south and upstream of the City of Libby. The Project is owned and operated by Pacific Power and Light Company of Portland, Oregon, as the City of Libby's only water supply storage reservoir.

FINDINGS AND EVALUATION

Flower Creek Dam is a concrete arch structure 55 feet high, 180 feet long which rests between the steep rock walls of Flower Creek Canyon. The structure is capable of impounding 221 acre-feet at normal operating pool, elevation 50 project datum, and 285 acre-feet at the top of the dam, elevation 55 project datum. Inspection criteria classifies this dam as intermediate in size and because of possible severe downstream effects of failure, the downstream hazard potential is high (Category 1). Inspection criteria recommends such projects safely handle a full Probable Maximum Flood (PMF). The PMF is the flood expected from the most severe combination of critical meteorologic and hydrologic conditions reasonably possible in the watershed. The PMF was assumed to occur in July or August as the result of a 6-hour summer thunderstorm over the 15.2 square mile drainage. The PMF causes a peak inflow of 44,000 cfs with a flood volume of 5535 acre-feet.

At the beginning of the storm, Flower Creek Reservoir was assumed to be at the spillway crest at elevation 50 project datum (approximately 2676 MSL). The spillways are uncontrolled and were assumed unobstructed. The relatively insignificant capacity of the outlet works was neglected. Because of limited spillway capacity the reservoir would rise to the top of the dam (project elevation 55) in about 2 hours, adding 64 acre-feet of surcharge storage to the 221 acre-feet of normal storage at the spillway crest. At the time of overtopping the total discharge over the spillways would have increased to 1790 cfs. Using this combination of discharge and surcharge storage, the project would handle less than ten percent of the PMF volume prior to overtopping the dam. At the peak of the PMF, the dam would be overtopped by a depth of 16 feet at an elevation of 71 feet project datum.

A preliminary stability analysis of the structure and a review of available documents and data concerning the original design and subsequent repair work, indicate the structure is stable under PMF conditions and is not expected to fail. Field investigations conducted in conjunction with repairs made in 1966 identified defective areas which were repaired. The repair work consisted of the replacement of one complete monolith and part of another as well as the grouting, patching and sealing of construction joints and deteriorated areas on the surface. Based on corings of the dam and close inspection of the surfaces, the remaining areas of the structure were judged to be sound. The visual inspection conducted under this Phase I effort revealed the repair work to be effective although in need of maintenance. Within the level of detail appropriate for a Phase I Inspection and based on the available materials data, the preliminary analysis shows the stresses in the dam to be within allowable limits.

This Phase I Inspection and evaluation identified no evident signs of instability or distress, however, there is little substantiated data relating to the foundation conditions, seepage pressures and abutment contacts. Also the upstream face of the dam has not been inspected since the repairs were completed and the condition of the patching and epoxy seal is not known.

RECOMMENDATIONS

1. Immediately develop a formal reservoir operation and emergency warning plan to minimize risk to the downstream inhabitants and property.

2. Take necessary steps to substantiate the assumptions and findings of this safety inspection. If original data cannot be obtained then conduct foundation and seepage investigations to verify conditions of stability for the structure. Prepare a complete stability analysis of the dam for record.

3. Inspect the upstream face of the dam and accomplish all necessary repair and/or modification work to insure the dam is structurally sound.

MORRISON-MAIERLE, INC.

Rodger C Foster

Rodger C. Foster, P.E.
Project Manager

PERTINENT DATA

FLOWER CREEK DAM, MT - 1458

Location:	Township 30N, Range 31W, Section 21, Latitude 48°21.8', Longitude 115° 34.75', Lincoln County, Montana
Watershed:	Flower Creek, 15.2 square miles
Owner/Operator:	Pacific Power and Light Company 920 S.W. Sixth Avenue Portland, Oregon
Purpose:	Municipal Water Supply
Type of Dam:	Concrete Arch
Design/Construction/Repair:	-Design by Public Utility Engineering and Service Corporation, Chicago, 1945. -Constructed by Midland Constructors, Inc., Chicago, 1945-1946. -Repairs designed by Stevens, Thompson, Runyan and Ries, Inc., of Portland, Oregon, 1966. -Repairs made by Prepakt Concrete Company, Seattle, WA, 1966.
Project Size:	Intermediate - Height - 55 feet at dam crest Storage - 285 acre-feet @ 55 feet
Downstream Hazard Potential:	High (Category 1)
Spillway Design Flood:	Full PMF - Peak Flow - 44,000 cfs. Volume - 5,535 acre-feet
Key Elevations: (Project Datum)	Elevation - 55 feet - Top of Dam 50 feet - Spillway Crests 11.5 feet - Outlet Pipes Center line 5.0 feet - Invert Diversion Opening
Reservoir:	Normal Pool Elev. - 50 feet project datum - 2,676 mean sea level Surface Area (Normal Pool) - 11.8 acres Normal Pool Length - 1,600 feet Storage Normal Pool - 221 acre-feet Max. Storage, Dam Crest (55 ft) - 285 acre-feet Surcharge Storage - 64 acre-feet Drainage Area - 15.2 square miles

Dam:	Hydraulic Height - 55 feet from streambed Structural Height - 58.6 feet approximately Crest Length - 117.8 feet excluding spillways Dam Width - 3.5 feet at crest 9.0 feet at base, crown section Variable Radius
Spillways:	Two Spillways, one at each abutment
North Spillway	Concrete Chute with Broad crested weir control Crest Length - 30.2 feet Crest Breadth - 3.5 feet Crest Elevation - 50.0 feet (project datum) Capacity - 915 cfs @ elev. 55
South Spillway	Concrete Chute with broad crested Weir control - provisions for flashboards but not used Total Length - 32 feet including 1 foot center pier and wing wall Crest Length Left bay - 14.5 feet Right bay - 15.5 feet Crest Breadth - 3.5 feet Crest Elevation 50 feet (project datum) Capacity - 875 cfs @ elev. 55
Outlet Works:	
Outlet Pipes	1-10" diameter CI and 1-12" diameter CI valve controlled outlet pipe through dam Elevation - 11.5 feet @ Center line Capacity - 35 cfs @ pool elevation 55 feet
Diversion Opening	3 Foot square, sluice-gated concrete opening through dam Invert elevation - 5.0 feet Capacity-300 cfs @ pool elevation 55 feet

CHAPTER 1

BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority and Scope.

This report summarizes the Phase I inspection and evaluation of the Flower Creek Dam, owned by the Pacific Power and Light Company of Portland, Oregon.

The National Dam Inspection Act, Public Law 92-367 dated 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers, to conduct safety inspections of non-federal dams throughout the United States. Pursuant to that authority, the Chief of Engineers issued "Recommended Guidelines for Safety Inspection of Dams" in Appendix D, Volume 1 of the U.S. Army Corps of Engineers' Report to the United States Congress on "National Program of Inspection of Dams" in May 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many federal and state agencies, professional engineering organizations and private engineering consulting firm. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

When necessary, the guidelines recommend a two-phased study procedure for investigation and evaluating existing dam conditions so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety condition of the dam.

(2) based upon an evaluation of the available data and a visual inspection.

(3) performed to determine if any needed emergency measures and/or if additional studies, investigations and analyses are necessary or warranted.

(4) not intended to include extensive explorations, analysis or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulics and hydrologic analyses and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases the Corps may proceed with Phase II studies but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise. The two phases of investigations outlined above are intended only to evaluate project safety and do not encompass in scope the engineering required to perform design or corrective modification work. The responsibility for implementation of the Phase I recommendations or initiating the Phase II studies rests with the dam owner and the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and no action or failure to act under this act shall be construed (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation of Flower Creek Dam is to determine if conditions exist which constitute a danger to human life or property so that timely corrective measures can be taken by non-Federal interests.

1.1.3 Inspection

The findings and recommendations presented in this report are based upon observations from an on-site inspection conducted 14 September 1978, a review of available construction drawings, a review of reports and drawings of repair work performed, and interviews with Mr. R.J. Kauzlarich, Local Manager of Pacific Power and Mr. S.A. deSousa, Senior Civil Engineer for Pacific Power. The safety inspection and evaluation were performed in accordance with the "Recommended Guidelines for Safety Inspection of Dams," (Reference 17).

Morrison-Maierle, Inc. personnel who conducted the field inspection were:

Rodger Foster P.E. - Team Leader, Water Resource Engineer;
Kenneth Wiegand - Geologist;
David Barnett - Structural Engineer.

Others presented during the inspection were:

Robert Clark - Montana Department of Natural Resources and Conservation;
R.J. (Joe) Kauzlarich - Local Manager, Pacific Power and Light Company.

Morrison-Maierle, Inc. Staff participating in the evaluation were:

Harold Eagle, P.E. - Sr. Vice President and Chief Engineer;
Mike Kaczmarek - Chief Geologist;
William Keith, P.E. - Chief Structural Engineer;
Ken Salo - Hydrology and Hydraulics.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

Flower Creek Reservoir is a water supply storage project for the City of Libby, Montana, owned and operated by Pacific Power and Light Company of Portland, Oregon. It is the city's sole water supply. The dam is located on Flower Creek in northwestern Montana about three miles south of Libby in Section 21 of Township 30N, Range 31W (Plate 1). Most of the 15.2 square miles of drainage contributing to the reservoir lies in the Kootenai National Forest although the dam site is outside of the forest boundary.

The 55-foot high, 180-foot long, concrete arch structure is formed between the narrow rock walls of Flower Creek Canyon. The first development downstream is located at the mouth of the canyon where residential and commercial development in Libby is encroaching on the Flower Creek flood plain. If the dam should fail there is a high potential hazard for the loss of many lives and for great economic loss. The project is therefore classified as having a high downstream hazard potential (Catagory 1).

1.2.2 Regional Geology

Flower Creek Dam and Reservoir are in the northern Rocky Mountain physiographic province. The area consists of high, rugged, forested northwest-southeast aligned mountain ranges separated by narrow valleys. The mountains are supported by late Precambrian units of the Belt Supergroup consisting of fine-grained clastic and carbonate rocks 17,000 to 40,000 feet thick. Rocks in the Belt Supergroup were deposits in a wide shallow basin as sand, silt, clay and calcium carbonate. Subsequent lowgrade metamorphism altered the clastic sediments to form quartzite, siltite, argillite and siliceous limestone and dolomite. The middle part of the Belt Supergroup is the Piegan

Group (chiefly the Wallace Formation in the western part of the province) and consists predominantly of carbonate rocks. The lower and upper parts of the Piegan Group contain large percentages of clastic rocks. The Wallace Formation is the predominant bedrock unit in the Flower Creek drainage and consists of three parts; (1) a lower gray-green clacareous argillite; (2) a medial sequence of ferruginous blue-green argillite, limestone and light-gray and white calcareous quartzite; and (3) an upper laminated blue-gray, gray-green and white argillite.

Flower Creek Dam is located on the east flank of an anticline trending north-northwest with its crest located approximately 1½ miles west of the dam. The approximate trace of an adjacent syncline located to the east follows Libby Creek in the valley. Another structural feature evident on a regional scale is the Quartz Creek fault which closely parallels the syncline and follows Quartz Creek from the north, the Kootenai River south to Libby and then is hidden under Quaternary gravels in the Libby Creek Valley. There is evidence of some faulting directly south of the dam, approximately 3 miles distant, but no evidence of past or recent faulting adjacent to the dam and reservoir area was observed either in the field or on the available geologic map (Plate No. 11).

1.2.3 Seismicity

Flower Creek Dam is located in Seismic probability Zone 2. The seismic probabilities used herein divide the United States into four seismic risk zones based on the record of the severity of shaking and the reasonable expectancy of earthquake damage. Seismic probability or risk in Zone 2 indicates that moderately destructive earthquakes may occur. Zone 2 corresponds to a potential intensity of VII on the Modified Mercalli intensity scale of 1931.

Flower Creek Dam and the surrounding area near Libby, Montana, have been shaken by minor earthquakes (Johns, 1970 Reference 9) but no significant damage to structures has been recorded. The potential for displacement of the foundation materials appears to be minimal with no evidence of a fault or fault trend present at or near the dam. Under the Recommended Guidelines, dams in Seismic Zones 0, 1, and 2 may be assumed to present no hazard from earthquake loading provided the dams can be shown to be stable under normal operational loads and conventional safety margins exist.

1.2.4 Site Geology

As shown by the geologic map on Plate No. 11, the geologic terrain at the dam and reservoir site consists entirely of rock of the Wallace Formation. The predominant rock type is slabby siltite with lesser amounts of interbedded quartzite, that dip an average of 50° east and strike about N17°W to N20°W. The consolidated bedrock in the abutments ranges in composition from green to light gray, thinly laminated (less than 2mm) siltite to green and gray, sandy, sericitic and ferruginous shale and includes some interbedded gray and brown quartzite. The rocks have micaceous (sericitic) partings along bedding planes. The rocks part along beddings and along a joint system consisting of one joint set that strikes N60°E and one joint set that strikes N30°W. Both joint sets dip perpendicular to the bedding of the rocks and display 1 to 2 feet joint spacing.

1.2.5 Description of Dam and Appurtenances

1.2.5.1 Dam and Spillways

Flower Creek Dam as shown in photo 1, is a concrete arch structure of variable radius and is sited in a deep narrow canyon formed by steep rock walls. At each abutment a nearly free overfall spillway is formed against the canyon wall with a steep concrete chute directing the water to the center of the stream channel about 50 feet downstream from the dam.

The dam rises 55 feet above the streambed and is a total of 180 feet long at the crest including both spillways, or 117.8 feet long between the spillways. The dam cross-section increases from a thickness of 3.5 feet at the crest to 9 feet at the base of the cross-section (Plate 8). A project datum is used by the owner and in this report to which reference is made in describing elevations and reservoir stage. The datum is based on the height dimensions of the dam with the spillway crests being at elevation 50 feet which places the top of the dam at elevation 55.

The south spillway (Photos 10-16) is 32 feet wide and has provisions for flashboards although none are used under present operating procedures. The spillway crest is a broad-crested weir with a breadth of 3.5 feet at an elevation of 50 feet; five feet lower than the top of the dam. The only access to the dam crest is across a wooden walkway (Photo 6), which spans the south spillway. A woven wire fence and gate (normally locked) at the walkway restricts access to the dam crest. The uncontrolled north spillway (Photos 17-20) is 30.2 feet wide at the weir and has no provisions for increasing the crest elevation.

1.2.5.2 Outlet Works

The project has two outlets (Photo 21-23) which are referred to in the construction drawings (Plate 8) as the outlet and the diversion opening. The outlet consists of two cast iron pipes, 10-inch and 12-inch diameter, through the dam with control valves located in a wooden valve house mounted against the toe of the downstream face of the dam. Originally a wooden stairway built from the south abutment across the face of the dam provided access to the valve house. The stairs were removed for public safety reasons and now access to the house must be gained by lowering a portable ladder from the crest of the dam. Due to the problems of inaccessibility the outlet pipes are not normally used in the operation of the dam.

The diversion opening is a three-foot-square, concrete conduit formed into the dam with an invert elevation of 5 feet. It is controlled by a direct pressure slide-mounted sluice gate on the upstream face of the dam. The gate is operated from the crest of the dam and provides the primary means of regulating operational releases from the reservoir. Approximately one mile downstream of Flower Creek Dam is a low head diversion dam which regulates flows to the City of Libby water supply system.

1.2.6 Design and Construction History

Flower Creek Dam was built by Mountain States Power Company in 1945 as a single purpose water supply reservoir for the City of Libby. It was designed by Public Utility Engineering and Service Coorperation of Chicago. Some prints of the original plan sheets were provided by Pacific Power and are reproduced at the end of this report on Plates 5 through 9. It is not known whether the drawings reflect as-built conditions although the basic dimensions agree closely with measurements taken during the on-site inspection. Midland Construction, Inc., also of Chicago, constructed the dam in 1945. Details of the construction are presented in Section 2.4 -Structural Conditions and Stability.

In 1954, Pacific Power and Light Company assumed ownership of the dam through the company's aquisition of Mountain States Power Company and presently operates the facility. Pacific Power contracted with the engineering firm of Stevens, Thompson, Runyan and Ries of Portland, Oregon, to investigate a condition described as accelerated deterioration of the surface concrete of the dam. The ensuing inspection included surface inspection of the concrete by a representative of the Portland Cement Association, core drilling of the dam by Lynch Bros. of Seattle, Washington, and laboratory analysis of the samples. The investigation recommended repair work be made which included the replacement of a defective monolith and some refacing and grouting. Repair work was performed in 1966 as is indicated on the plan sheet reproduced on Plate 10 of this report. A more detailed discussion of the 1966 investigation and findings is presented in section 2.4 of this report.

1.2.7 Physiography, Climatology, and Hydrology

The Flower Creek drainage lies in the eastern exposure of the Cabinet Mountains in the Kootenai River basin of northwestern Montana. The Cabinet Mountains rise nearly 6000 feet above the Kootenai River to elevations over 8000 feet. The Continental Divide lies 100 miles to the east with two parallel northwest southeast oriented ranges lying between the divide and Flower Creek. The mountain barriers to the east, range in elevation from 5,000 to 10,000 feet.

The 15.2 square mile Flower Creek drainage above the dam rises from approximately 2,676 feet at normal pool elevation to 7,568 feet at Sugarloaf Mountain in a stream length of 7.5 miles as is shown on Plate 2. Ninety-two percent of the drainage is in forest cover with an established undergrowth. The remaining eight percent of the drainage is in mountain grass cover or is exposed rock faces. The valley upstream of the dam is a narrow "V" shape approximately seven miles long and averaging two miles across from divide to divide. In the upper drainage there are three natural lakes of about 25 to 50 surface acres in size which could provide some routing for no more than 10 percent of the drainage.

There are no stage or flow measuring devices at the dam. Reservoir stage is determined by measuring from the sill of the spillways which are at a stage of 50 feet above the stream bed. There is a USGS stage recorder (123031) on Flower Creek one mile upstream from the reservoir and about .3 miles upstream of the South Fork of Flower Creek with records since 1950. It has a drainage area of 11.1 square miles and experienced a maximum discharge of 709 cfs in January, 1974. Three miles downstream of the dam at Libby there is a recording temperature and precipitation station (Libby 1 N.E. Ranger Station, elev. 2080), with 71 years record for temperature and 81 years for precipitation. Average annual precipitation at the station is 19.4 inches with nearly 40 percent of it occuring as snow in the months November through January. In the drainage area the average annual precipitation is about 70 inches according to USGS open file report 75-650. Snow surveys are taken by the U.S. Soil Conservation Service and the U.S. Forest Service at nineteen stations in the Kootenai River Basin but the nearest is Cedar Grove fifteen miles south of Flower Creek.

CHAPTER 2

INSPECTION AND RECORDS EVALUATION

2.1 SPILLWAY DESIGN FLOOD

Flower Creek Dam is 55 feet high and capable of impounding 285 acre-feet which classifies it as an intermediate-sized dam. It has a high downstream hazard potential due to residential and commercial development along Flower Creek at Libby. The inspection criteria recommends that the spillway design flood (SDF) for high hazard, intermediate-sized dams to be a full probable maximum flood (PMF).

2.2 HYDRAULICS AND STRUCTURES

The dam has two spillways, each formed into the top of the dam at either abutment. Both spillways direct flow to the rock canyon downstream of the dam. Therefore, energy dissipating structures are not required. The outlet works consist of two valved pipes, 10 inches and 12 inches inches in diameter, and a three-foot-square, sluice-gated diversion opening near the base of the dam. Drawings and inspection photographs showing the design details are presented following the text of this report.

2.2.1 South Spillway

The south spillway consists of an arched gravity section at the south abutment of the dam and is formed into the rock canyon wall. Design details are shown on Plate 5, and in photos 10 through 16. The spillway crest is at an elevation of 50 feet. Its total width is 32 feet, including a 12-inch concrete pier approximately centered in the opening. The breadth of the spillway sill is 3.5 feet. Wooden flashboard supports are anchored to the sidewalls and pier, and metal support pipes are placed in the concrete sill at the midpoints of the openings (Photo 12). Flashboards were not in place during the inspection and are not used in the operation of the reservoir. The south abutment is the entrance point to the crest of the dam and a wood walkway is constructed across the spillway to allow access to the dam. The low chord of the walkway is at elevation 56.

The spillway rating curve was developed based on a broad-crested weir control with weir lengths of 14.5 feet and 15.5 feet for each bay. For heads (H) up to five feet, or equal to the top of the dam, a weir coefficient (C) of 2.8 and end contraction losses of 0.2 H were used. Above five feet a "C" value of 3.3 was used. It was also assumed that the wooden walkway would not remain in place and therefore not act as a restriction to flow. Maximum discharge over the spillway before dam overtopping is estimated to be 875 cfs. The spillway rating curve is shown on Plate 4.

2.2.2 North Spillway

The north spillway consists of a concrete gravity section at the north abutment and is formed into the rock canyon wall. Design details are shown on Plate 6 and in Photos 17 through 20. Flow over the spillway spills down a steep concrete lined chute formed over the natural rock before plunging down the rock canyon wall to Flower Creek. The spillway crest is at an elevation of 50 feet, the same as the south spillway. There are no provisions for flow control at the north spillway.

A hydraulic analysis was performed to develop a spillway rating curve for the north spillway (Plate 4). The analysis was based on a broad-crested weir control with a weir length as measured in the field of 30.2 feet. A weir coefficient of 2.8 and end contraction losses of 0.2H were used for heads up to five feet and above five feet a weir coefficient of 3.3 was used. Maximum discharge over the spillway before overtopping of the dam occurs is estimated to be 915 cfs.

2.2.3 Dam Overtopping

At pool elevations greater than 55 feet project datum, the entire length of the dam will be overtopped. A hydraulic analysis of the overtopping condition was made for the section of dam between the spillways. The analysis was based on a free overfall weir control with a weir length along the downstream edge of 117.8 feet as measured in the field. A weir coefficient of 3.3 was used with no end contraction losses. The estimated discharges which would pass over the center dam section would range from 12,200 cfs at a head of 10 feet to 34,500 cfs at a head of 20 feet over the dam. A combined discharge rating curve for the dam section and spillways is presented on Plate 4.

During overtopping, water would plunge onto the bedrock at the base of the dam. The bedrock immediately downstream of the dam (see photo 5) is competent to withstand flow impingement without jeopardizing the safety of the dam.

2.2.4 Outlet Works

Releases from the reservoir can be controlled in two ways; through two outlet pipes or through a diversion opening. The outlet, as detailed on Plate 8, consists of a pair of cast iron pipes 10 and 12 inches in diameter that extend through the dam approximately nine feet north of the crown of the arch. The centerline of both pipes is at elevation 11.5 feet. Flow through the pipes is controlled by valves located in a wooden valve house situated at the downstream base of the dam as shown in Photo 21, and, Plate 8. Originally, wooden stairs constructed from the south abutment across the face of the dam to the bank of Flower Creek provided access to the valve house. The stairs were removed as a safety precaution. Access to the valve house is now gained with the aid of a long ladder which must be lowered from the crest of the dam. Because of inaccessability, the outlet pipes are not now used as a primary means of regulating releases. Maximum combined discharge capacity of the pipes is estimated to be 35 cfs.

The diversion opening is a three-foot-square conduit formed through the dam and controlled with a sluice gate at the upstream opening. The diversion opening is shown on Plates 7 and 8 and in Photo 23. The opening is located about 10 feet south of the crown of the arch with an invert elevation of five feet. It is the primary means of regulating releases from the reservoir. The sluice gate located on the upstream face of the dam is a direct pressure, slide-mounted gate, controlled from a gate stand at the crest of the dam. Maximum capacity of the diversion outlet is estimated to be 300 cfs.

Because of the relatively insignificant discharge capacity of both the diversion opening and the outlet pipes, and because it is likely neither would be accessible during an extreme flood event, the capacities of the outlet works were not included in the safety analysis of the dam.

2.2.5 Flower Creek Channel Downstream

Water surface profiles were computed on Flower Creek immediately downstream of the dam in order to establish tailwater elevations. The U.S. Army Corps of Engineers computer program "HEC-2 Water Surface Profiles" was used for the analysis with a typical channel cross-section taken from the dam elevation detail on Plate 6 and channel slope determined from USGS Quadrangle Map Little Hoodoo Mountain. Using Manning's "n" values of .05 for the channel and .06 for the overbanks, the slope of 5.3% produced a supercritical flow profile. Tailwater conditions during overtopping of the structure were evaluated as though the dam section functioned as a straight drop spillway. The tailwater depth under the nappe and against the dam face was computed by a straight drop spillway analysis (Reference 5). This analysis yielded a tailwater depth of 25 feet for the PMF.

2.2.6 Freeboard

Between normal operating pool at the spillway crest and the top of the dam there is five feet of freeboard. A highwater mark measured during the inspection is at elevation 51.4 feet. Due to very limited flood storage capabilities, the dam is quickly overtopped under major flood events. Wind generated waves on the reservoir, which have a maximum fetch length of approximately 1,600 feet, would be negligible in terms of wave height or effect on dam safety.

2.3 HYDROLOGY

2.3.1 Reservoir Stage and Storage

A stage - storage relationship was developed for Flower Creek Reservoir for use in the PMF routing analysis. The owner provided a capacity curve to an elevation of 50 feet. To extrapolate the curve to higher stages an analysis was made using the conic method of estimating volume and topography from the USGS Little Hoodoo Mountain 7½ minute Quadrangle map. The resulting Stage - Storage curve is shown on Plate 3. Between normal pool elevation at the spillway crest and the top of the dam there is 64 acre-feet of storage available. At the top of the dam the reservoir impounds 285 acre-feet.

2.3.2 Preliminary Probable Maximum Flood (PMF)

The spillway design flood (SDF) for Flower Creek Dam is a full PMF. A preliminary estimate of the probable maximum precipitation (PMP) which can be expected on the drainage was developed using procedures outlined in Hydrometeorological Report (HMR) #43, as modified by U.S. Weather Bureau memorandum dated 9/20/67 (Reference 19).

A six hour July-August thunderstorm was determined to produce the most critical storm conditions when applied to the basin and yields a PMP of 7.6 inches. The watershed soils are of a hydrologic group B with moderate infiltration rates. The antecedent conditions to which the PMP was applied assumed a saturated but snow-free watershed with a minimum loss rate of 0.15 inches per hour. The storm was applied in 15 minute increments arranged in a critical time sequence according to HMR #43, figure 5,e. A unit hydrograph was developed for the watershed using procedures outlined in "Design of Small Dams," (Reference 20). Using the U.S. Army Corps of Engineers' "Flood Hydrograph Package, HEC-1,"(Reference 15), the unit hydrograph and PMP values were combined with a base flow of 50 cfs to produce a probable maximum flood hydrograph. The PMF hydrograph peaks at 44,000 cfs in 4.5 hours with a total volume of 5,535 acre-feet and duration of 7.5 hours.

2.3.3 Routing of the Preliminary Probable Maximum Flood

Routing of the probable maximum flood through Flower Creek Reservoir was performed using the computer program HEC-1 Flood Hydrograph Package as was the development of the flood hydrograph. For the routing analysis, it was assumed the initial pool elevation at the beginning of the storm would be at normal pool which is at the spillway crest. Neither the capacity of the outlet pipes nor the diversion opening were considered in the routing analysis because of their relatively insignificant capacity compared to the PMF, and because of the inaccessibility of operating controls during an extreme flood event.

The routing analysis indicates that the dam will be overtopped during the PMF when less than ten percent of the volume has entered the reservoir. At peak flow it will be overtopped by 16 feet. Because of limited surcharge storage the reservoir has essentially no effect on flood routing at high flows. As a comparative analysis, flood hydrographs representing 10%, 30%, 50%, and 70% of the PMF flow were also routed through the reservoir. The 10% PMF flow caused the dam to be overtopped by 1.5 feet.

2.4 STRUCTURAL CONDITIONS AND STABILITY

No stability analysis of the structure was found which could be reviewed by the inspection team. Assessments of the structural conditions and stability are based on the 14 September 1978 on-site inspection, a review of plans showing original design details, reports on repair work performed in 1966 (References 1, 2, 7, 13, 14) and a stress analysis performed as part of the safety inspection. Construction information and concrete test data were made available by the owner in documents pertaining to the 1966 repair work. No field geotechnical data was available except as shown on the original design drawings (Plates 5-9) and on the Plate 10 showing Flower Creek Dam Physical Defects identified in 1966.

2.4.1 General Dam Condition

In 1966, extensive repair work was performed on Flower Creek Dam which involved the replacement of a monolith, patching of deteriorated concrete, and grouting and sealing of construction joints. At the time of the inspection, (9/14/78), the concrete and patching on the downstream face of the dam appeared to be in good condition (Photos 3, 8, 9). Some minor seepage is occuring through construction joints on the south side of the dam and small areas of the patching near the center of the dam appear to be spalling away. None of this observed deterioration appears to be serious.

The south spillway is a concrete gravity weir formed in two bays separated by a concrete pier. Present condition and configuration of the south spillway is shown in Photos 10 through 16. A steep concrete chute with concrete side-walls is formed against the rock abutment and directs the water down the canyon wall to Flower Creek. The upper portion of the spillway chute is poured over the rock and the lower portion is a natural rock section (Photo 10). Some minor erosion of the concrete sill (about 0.1 foot, Photo 15) was observed which should be expected for the climate and the age of the dam. The floor of the chute was obscured from view due to spilling water. There are minor areas of spalling on both the inside and outside of the left training wall as shown in Photos 13 and 14, and a crack exists in the training wall where it connects with the dam section (Photos 12 and 16). The crack is adjacent to the flashboard supports and should be repaired. The walkway across the spillway is generally in good repair and a woven wire fence provides an excellent safety feature.

The north spillway is also an uncontrolled gravity weir section with no obstructions. Its present condition and configuration is shown in Photos 17 through 20. The concrete spillway chute rests on the rock wall with the rock abutment forming the left chute wall. A short wing wall on the right directs the flow down the canyon wall to Flower Creek (Photo 17). A crack and concrete deterioration was observed in the right wing wall (Photos 18 and 19) through which water was observed seeping at a rate too small to measure. Also a small portion of the downstream edge of the wing wall had broken away exposing some rebar.

From the visual inspection the dam appears to be in good structural condition. Observed areas of deterioration and defects would not indicate a threat to the stability of the structure.

2.4.2 Summary of Repairs and Inspections

A significant amount of data was obtained in connection with a major repair performed on the dam in 1966. Reports on the field investigation and recommended repairs, and reports on the repair construction were reviewed and considered in this Phase I Inspection. In 1977, ten years after the repairs were completed, Pacific Power conducted an inspection of the structure with a representative of Intrusion Prepakt Company, who performed the repair work. The report of that inspection was also reviewed. The information provided in these historic reports is summarized in this section in order to provide a structual history of the structure.

- Stevens, Thompson, Runyan and Ries, Inc. Investigation Report, June 14, 1966:

In the summer of 1966 the Firm of Stevens, Thompson, Runyan, and Ries, Inc. conducted an investigation of the physical conditions of Flower Creek Dam (Reference 13). The investigation involved a thorough inspection of the exposed concrete, core drilling of the structure, and laboratory testing to determine concrete strength, aggregate reactivity, and chemical composition of lime deposits taken from the downstream face. Assisting in the investigation were Lynch Bros., of Seattle, Washington who performed the core drilling, and a representative of the Portland Cement Association. The investigation revealed the following findings:

a. The lower portion of the downstream face was coated with a heavy layer of lime;

b. Nearly all horizontal construction joints were in bad condition with leakage through them varying from surface dampness to flowing streams;

c. The monolith located in the 3rd level down at the north abutment was made of defective concrete. Extensive concrete spall was noted and no concrete could be recovered from a vertical core through this monolith;

d. Laboratory analysis of the material recovered from the 3 vertical cores and 2 horizontal cores taken indicated that except in the defective monolith the interior concrete was sound with low aggregate reactivity and high compressive strength, over 5000 psi;

e. Many of the surface defects were concentrated in certain monoliths which indicates that poor quality control of the concrete mix was part of the problem;

f. The severity of climate and the absence of an air-entrainment admixture contributed to the surface deterioration.

Defects noted from the investigation are shown on Plate 10. The following repair work was recommended:

a. The deteriorated concrete at all surfaces and joints be removed down to sound concrete and patched with either dry packed or poured concrete. An epoxy bonding agent was recommended to insure a more permanent repair;

b. The defective monolith be completely removed and replaced with air-entrained concrete and the construction joints be re-grouted after shrinkage.

c. All horizontal and vertical construction joints be re-grouted.

The report also recommended that to minimize temperature changes on the upstream face of the dam that the reservoir pool be maintained at the highest possible level at all times.

- Flower Creek Dam Construction Reports, January 5, 1967, July 31, 1967:

Recommended repairs were accomplished by Prepakt Concrete Company of Seattle, Washington beginning in August of 1966 (Reference 1). The following repair items were noted in construction reports prepared by the inspector:

a. Lime deposits were removed by hand scraping and with an air chipping hammer. Some hard to get at deposits, such as under the stairs, remained.

b. Deteriorated concrete on the downstream face was removed by chipping. To reduce the possibility of sizeable leaks through the joints during the chipping operation, the reservoir level was lowered. Also, as the reservoir level was lowered, deteriorated concrete along the uppermost horizontal construction joint on the upstream face was removed. Concrete was removed to a depth of up to 12 inches and a mat of resteel, #5's @ 12 inches each way, was tied to the form tie rods, which were anchored in the remaining concrete. As chipping progressed it was seen that considerably more deteriorated surface concrete was present than originally thought. Approximately 40 percent of the downstream face and 20 percent of the upstream face was replaced. A diver was employed to inspect the upstream face below an elevation of 30. No spalled concrete was found.

c. The defective monolith was removed as well as the lower half of the adjacent monolith which was also determined to be defective. Eleven 6-inch by 6-inch H Columns were wedged into place at approximate 5-foot intervals to support the concrete above. These steel members were left in place when new concrete was placed.

d. By the time concrete work was completed cold weather had arrived with only the afternoon hours above freezing. Because of this and other reasons it was decided to delay grouting of the joints until the following spring.

Final repairs to Flower Creek Dam were completed by the Prepakt Concrete Company in June of 1967, and a final report dated July 31, 1967 (Reference 2) was filed with Pacific Power and Light. This report states that drilling and grouting of the joints was not effective in stopping the flow of water through the joints and it was decided to apply an epoxy coat on the joints and cracks on the upstream face. Approximately 1000 feet of joints and cracks were covered with an epoxy labeled "Concresive #1063-1" manufactured by Adhesive Engineering Co. of San Carlos California. On July 19, 1967 the dam was observed and little or no joint seepage was reported.

- Dam Inspection Report, 1977:

On May 12, 1977 Flower Creek Dam was visually inspected by Messrs. Hector and deSousa of Pacific Power and Light and Mr. David Logan of the Prepakt Concrete Company (Reference 7). Following is a summary of their findings:

a. The upstream face, where visible, appeared in good condition.

b. The downstream face was in good condition with only minor spalling visible on the monolith adjacent to the valve house which was not resurfaced in 1966. Leakage through joints was minor and negligible except along the joint at the top of the monolith that was completely replaced in 1966.

c. At the right (south) spillway the timber flashboard supports were in deteriorated condition. In the training wall adjacent to the dam a crack about 2 feet from the upstream face of the dam and a small area of concrete spall were noted.

d. At the left (north) spillway the concrete was worn so that aggregate was exposed. A crack in the training wall with water seeping through was also noted.

The items observed during the Phase I Inspection on September 14, 1978 agreed very closely with the inspection report by Mr. deSousa in 1977.

Based on a review of all previous inspection reports and the on-site inspection it appears that:

(1) Repairs to the dam in 1966 and 1967 to correct surface deterioration on both faces of the dam and to halt seepage through the dam were effective. However, as can be seen in photos 7, 8 and 9 minor seepage through the dam is continuing which is depositing lime on the downstream face of the dam.

(2) On the basis of the high concrete compressive strengths found in cores taken from the interior of the dam in 1966, it can be concluded that the dam is basically sound.

(3) Because the areas not resurfaced in 1966 consist of non-air-entrained concrete, surface deterioration will probably continue in the future due to the severity of the climate. However, because most of the poor quality concrete has been replaced this deterioration should proceed at a much slower pace than that experienced in the past.

2.4.3 Foundation Conditions, Seepage and Drainage

2.4.3.1 Foundation Conditions:

Investigations and plans for Flower Creek Dam compiled prior to construction do not include any drill hole data or other subsurface information regarding foundation materials. However, engineering drawings labeled "Libby, Montana Reservoir - Foundation Grouting, November 29, 1945" (Plate 9) show a profile of the dam with an "original ground" surface and "bottom of trench" surface. The cross-section also shows the location of grout holes with a 5-foot spacing penetrating approximately 15 feet into the bedrock foundation. The magnitude and distribution of seepage pressures and the amount of seepage through the grouted foundation is unknown.

Another drawing entitled "Flower Creek Dam, Physical Defects" (Plate 10) prepared for Pacific Power and Light Co. in 1966 depicts the concrete structure keyed into the foundation approximately 3½ feet. Three vertical core holes drilled in 1966 through the dam did penetrate the concrete-bedrock interface according to the drawing. There is, however, a discrepancy in regards to bedrock depth in the core holes on Plate 10 in the upstream view versus the downstream view and also in relation to the 1945 preconstruction drawing (Plate 8). The discrepancy is greatest at core hole "BX" Hole No. 2 on Plate 10 which shows a 4-foot 10-inch difference. Uncertainty exists as to the depth which the concrete dam structure is keyed into the bedrock and cannot be resolved with the information available at this time. During the field inspection it was not possible to examine the downstream toe of the dam due to recent material deposited at the base and the water pool at the discharge opening (Photos 8, 21 and 23).

The abutment material does not show signs of deterioration, structural weaknesses or stability problems. The right abutment is a bedrock dip slope with the spillway apron placed conformably on the siltite. The left abutment is hard siltite with some interbedded quartzite.

2.4.3.2 Seepage Conditions and Drains

During the field safety inspection on 14 September 1978 no significant seepage problems were observed. Although one small seep about 20 feet downstream from the south spillway was noted, no abnormal phreatophyte plant growth or unusual erosion patterns exist downstream from the dam. The existing seep located about 5 vertical feet above the stream bottom was dripping from a joint in the bedrock at a rate too small to measure. Drains installed in the spillway structures for seepage control were observed during the field inspection. However, flow over the spillway obscured any indication of seepage. The drain in the north spillway is shown in Photo 17. There was no seepage evident in the abutment bedrock and the determination of seepage conditions in the foundation bedrock was not possible due to the tailwater and discharge from the diversion opening.

2.4.4 Structural Stability Analysis

Flower Creek Dam is a variable radius concrete arch dam with all arches symmetrical or very nearly symmetrical about the centerline. The dam is approximately 55 feet high at the centerline and is about 117 feet long along the downstream edge of the crest. In addition to this, there are two spillways about 31 feet long, one at each abutment; the crest of both spillways is 5 feet below the top of the dam. The dam is constructed of monoliths with horizontal construction joints spaced 10 feet apart with the top two monoliths 7.5 feet high. There are three vertical contraction joints at the quarter points which were grouted about 6 months after pouring of the monoliths was completed.

An arch dam resists applied loads by a combination of arch and cantilever action which transfers loads to the canyon walls. The arch dam is not subject to the same type of sliding and overturning conditions as a gravity dam and is considered stable against such failure if the rock in the abutments has no planes of instability and can resist the applied loads. There is no evidence of instability in the abutments and the dam is considered stable with regard to sliding and overturning.

An arch dam is considered stable if the stresses within the concrete of the arch are less than allowable values. For the purposes of this safety evaluation an approximate method for determining stresses in arch dams was used based on the elastic theory of design as outlined by Creager, Justin and Hinds (Reference 6). Simplifying and conservative assumptions were used in the calculations to assess the general adequacy of the design.

Stresses within the dam were computed resulting from pool elevations of 50 feet, 55 feet, and 71 feet (PMF). Forces resulting from the tailwater were ignored to provide a conservative assessment. Stresses were calculated at the crown and abutments, at the upstream edges and downstream edges, and at elevations of 40 feet, 20 feet, and 10 feet within the dam. Ice effects were not considered. Computed stresses were compared to allowable stresses based on ACI 318-63 and assumed in-situ concrete compressive strength of 3000 psi which are:

Compression $.45\ f'c$ =	1350 psi
Tension $1.6\ \sqrt{f'c}$ =	88 psi
Bearing $.25\ f'c$ =	750 psi

None of the stresses calculated were considered high or unsafe, indicating that the dam is stable from being overstressed for all conditions investigated including overtopping during a PMF.

2.5 PROJECT OPERATIONS AND MAINTENANCE

Flower Creek Dam is owned and operated by Pacific Power and Light Company. The project is a water supply storage facility which controls flows to a small diversion dam located about one mile downstream. Normal operational policy is to fill the reservoir as soon as possible in the spring and to maintain as much storage as possible as long as possible through the dry season. The reservoir is also maintained at as high a level as possible so as to minimize the effect of extreme temperature changes on the upstream face of the structure. The project is not operated for flood control.

The reservoir operator resides and works in Libby and visits the dam as release requirements demand. The local office of Pacific Power maintains no formal operational plan or operational records for the reservoir.

Major maintenance and repair work was performed on the dam in 1966 and 1967 and was well documented as described in section 2.4 of this report. The next documented inspection of the structure was performed in 1977 by Pacific Power Senior Engineer deSousa and Mr. David Logan of Intrusion Prepakt Company. No records were available which would indicate inspections or maintenance were performed on the dam in the interim period. Since the dam is on private land, the U.S. Forest Service has not inspected the facility either.

The personnel in the Libby office of Pacific Power have not experienced a flow which would tax the capacity of the structure or require emergency notification procedures. The personnel were, however, aware of appropriate emergency warning procedures but no formal warning plan exists.

Pacific Power has gone to great lengths to restrict public access on the around the dam for safety reasons. A woven wire fence with a locked gate has been placed at the walkway on the south abutment, and a wood stair to the valve house was removed entirely. In spite of their efforts, Pacific Power reported a continuing problem with tresspassing and vandalism.

2.6 SAFETY EVALUATION

Flower Creek Canyon downstream of the dam is very narrow and deep for approximately two miles before it opens into the Kootenai River Valley at Libby. The first residences are located about 2.2 miles below the dam. Between the first residences and the Kootenai River, 4.6 miles downstream, there is substantial residential and commercial development.

Some residences would possibly be affected by the 1970 cfs passing the dam prior to the overtopping. In a PMF event that flow would be reached at approximately the second hour. Beyond that point in the flood, the reservoir has little routing capability and a peak flow of 44,000 cfs would be passed down the channel at about the fourth hour, or about 2 hours after overtopping occurs. Flood depths during a PMF event are estimated to be in excess of 15 feet at the mouth of the canyon. However, because the dam has a negligible effect on flood routing it has no added effect on flooding downstream when compared with natural conditions.

CHAPTER 3

FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Flower Creek Dam is an intermediate sized dam with high downstream hazard potential. Based on the hazard classification and project size, inspection criteria recommends the project safely handle a spillway design flood of a full PMF. The hydrologic and hydraulic analysis performed under this Phase I Inspection indicates the PMP would probably occur in July or August and produce a flood having a peak of approximately 44,000 cfs and a volume of 5535 acre-feet. With a total spillway capacity of less than 2000 cfs and a surcharge storage of 64 acre-feet, the project has little flood routing capability and the structure will be overtopped quickly. It is estimated that a full PMF will overtop the dam by 16 feet and a flood equal to one-tenth of a PMF will overtop the structure by 1.5 feet.

The findings of the structural analysis conducted at a preliminary level of investigation appropriate for a Phase I Inspection, indicate the structure is stable under PMF conditions. The analysis of stresses within the dam shows all computed stresses to be within allowable limits. Field data obtained during a repair effort conducted in 1966 supports conclusions that the dam is basically sound with no major defects remaining which would threaten the immediate safety of the dam.

Under high flow conditions Flower Creek Dam is in effect a run-of-the-river structure with the inflow to the reservoir equaling the outflow over the dam. The reservoir has little or no routing effect. Because the structure is stable there would be no flood surge caused by the dam and the flows downstream would be the same as flows expected under natural conditions.

It is the findings of this Phase I Dam Safety Inspection that within the limits of the investigation the structure is sound and stable. However, no preconstruction site investigation information or as-constructed data was available to provide a full assessment of foundation stability. A more thorough field investigation and structural analysis or the recovery of original design and construction data would be required to verify and document such a finding.

3.2 RECOMMENDATIONS

Project records along with the visual inspection indicate no evident distress or problem areas in the dam. The following recommendations are made to provide necessary supportive evaluations and to establish procedures which will verify and document the structural and operational safety of the project:

a. Immediately develop a formal emergency operations plan for warning people in the event of flooding or structural distress.

b. Make every effort to obtain the original design and construction data to verify and document the findings of this inspection. Specifically, the foundation and material investigation and the construction records of the orignal structure need be obtained. Also the boring logs from the 1966 repair work need be obtained to clear up the question of the location of bedrock beneath the dam. If the original data is not available, make the necessary foundation and seepage investigations to verify and document the assumptions used in the stability evaluation of this inspection. Prepare a complete stability evaluation of the dam for record.

c. Establish a formal and routine inspection and maintenance program including a formal reporting procedure. Conduct a complete inspection of the project at least every five years by a qualified engineer. Inspections should include a visual inspection of the upstream face during drawdown condition.

These recommendations will provide the necessary information to document the safety of the project. The recommendations will also establish an operational and maintenance plan which will insure the project will be operated in a safe condition and allow the owner to provide warning of potentially hazardous conditions.

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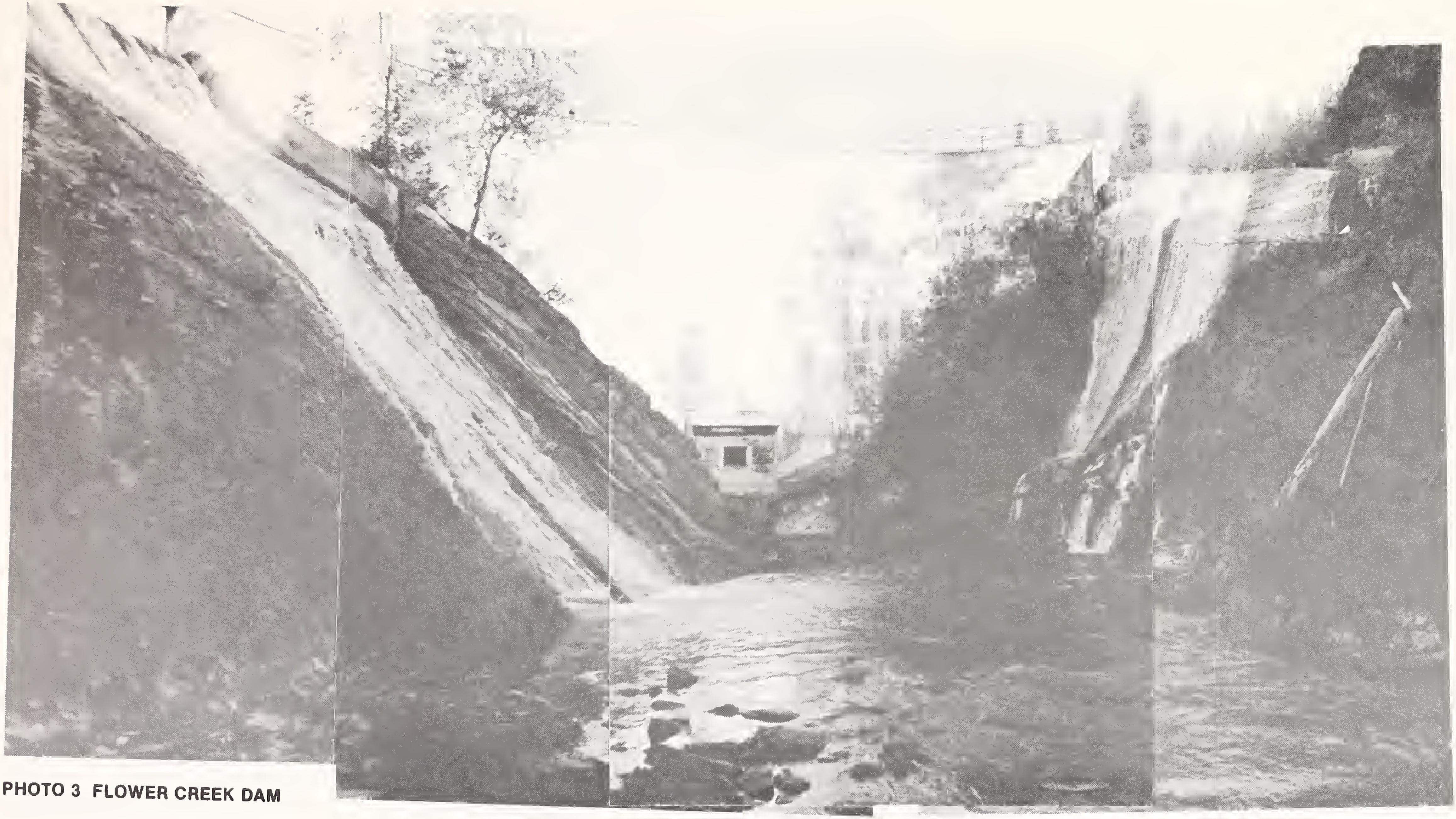


PHOTO 3 FLOWER CREEK DAM

FLOWER CREEK DAM

INSPECTION PHOTOGRAPHS TAKEN SEPTEMBER 14, 1978

PHOTO 4 FLOWER CREEK RESERVOIR TAKEN FROM DAM

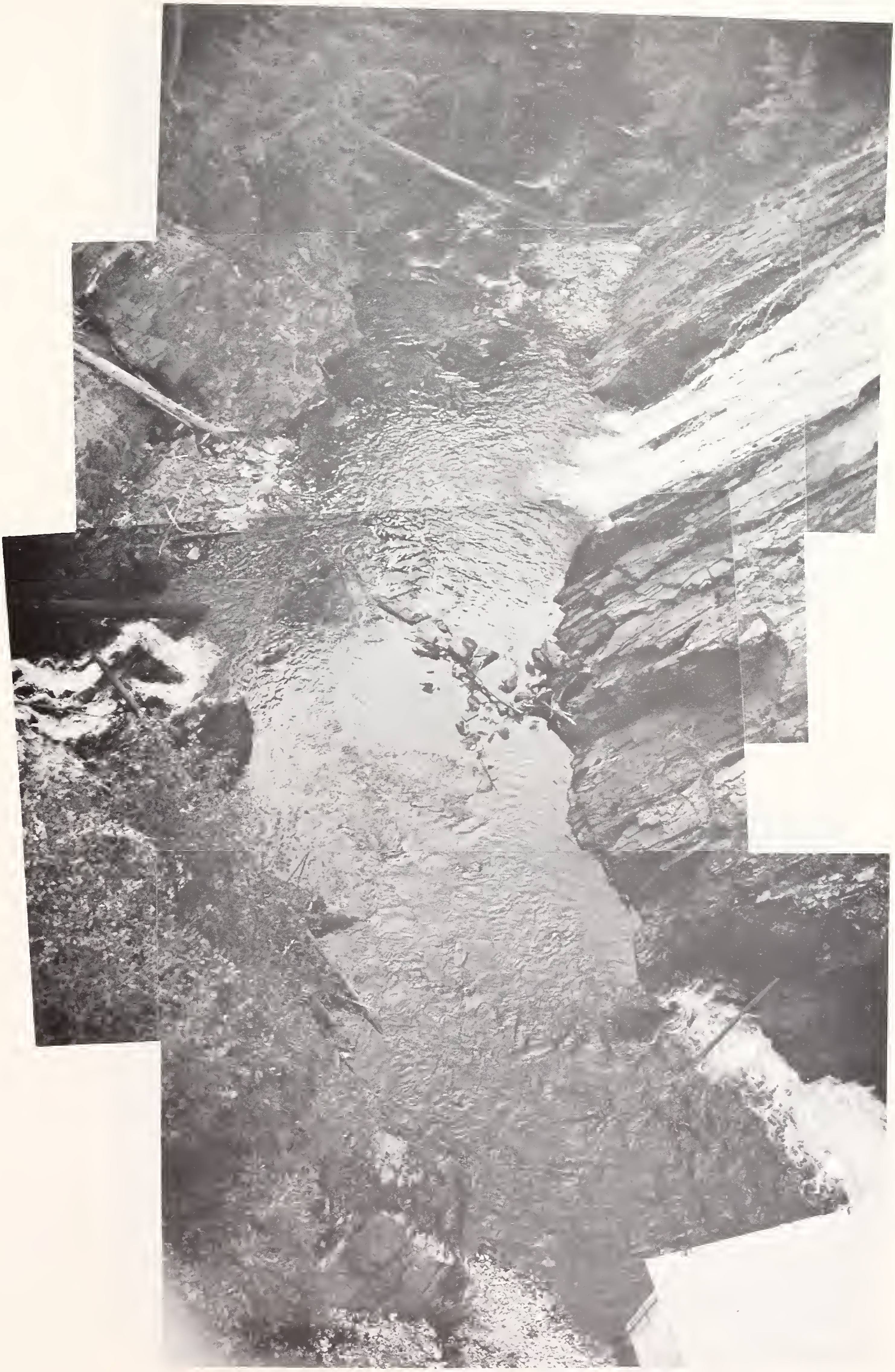


PHOTO 5 FLOWER CREEK CHANNEL DOWNSTREAM OF DAM

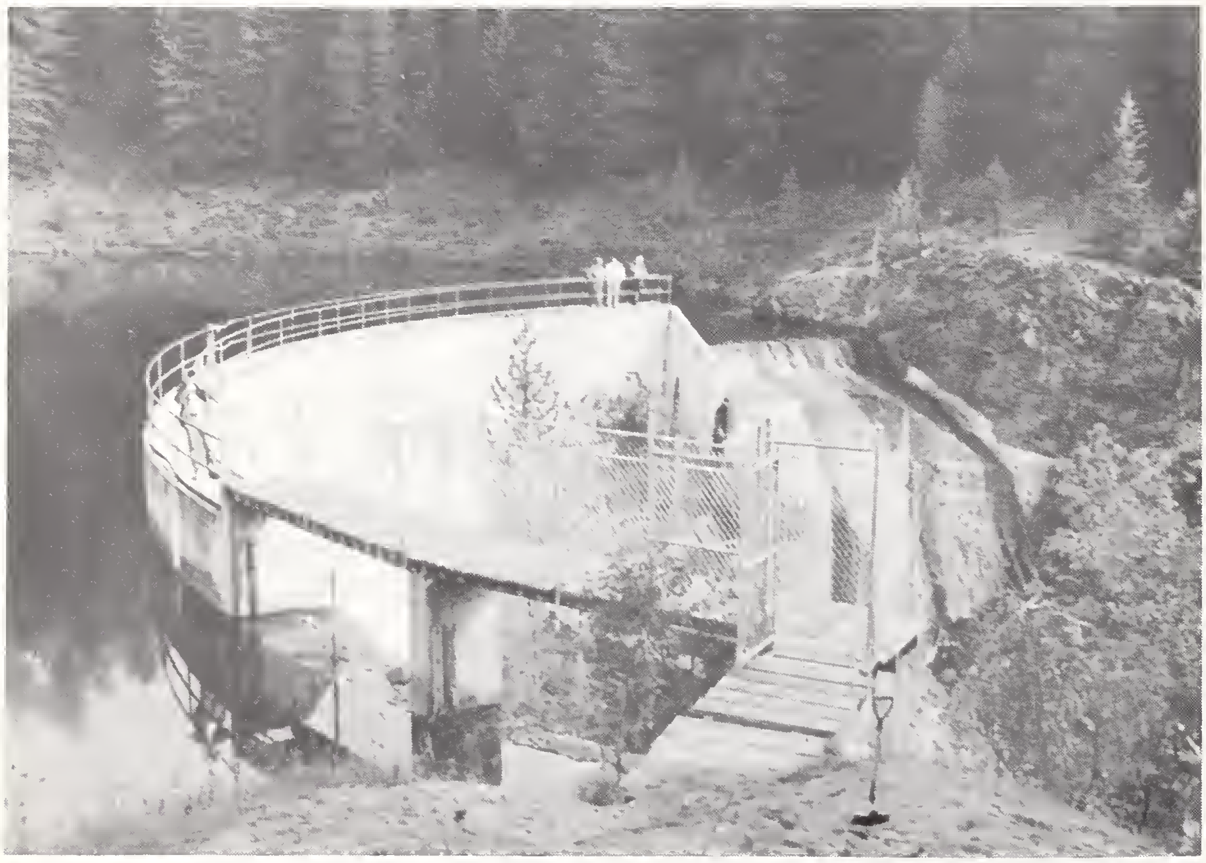


PHOTO 6 CREST OF DAM FROM SOUTH ABUTMENT

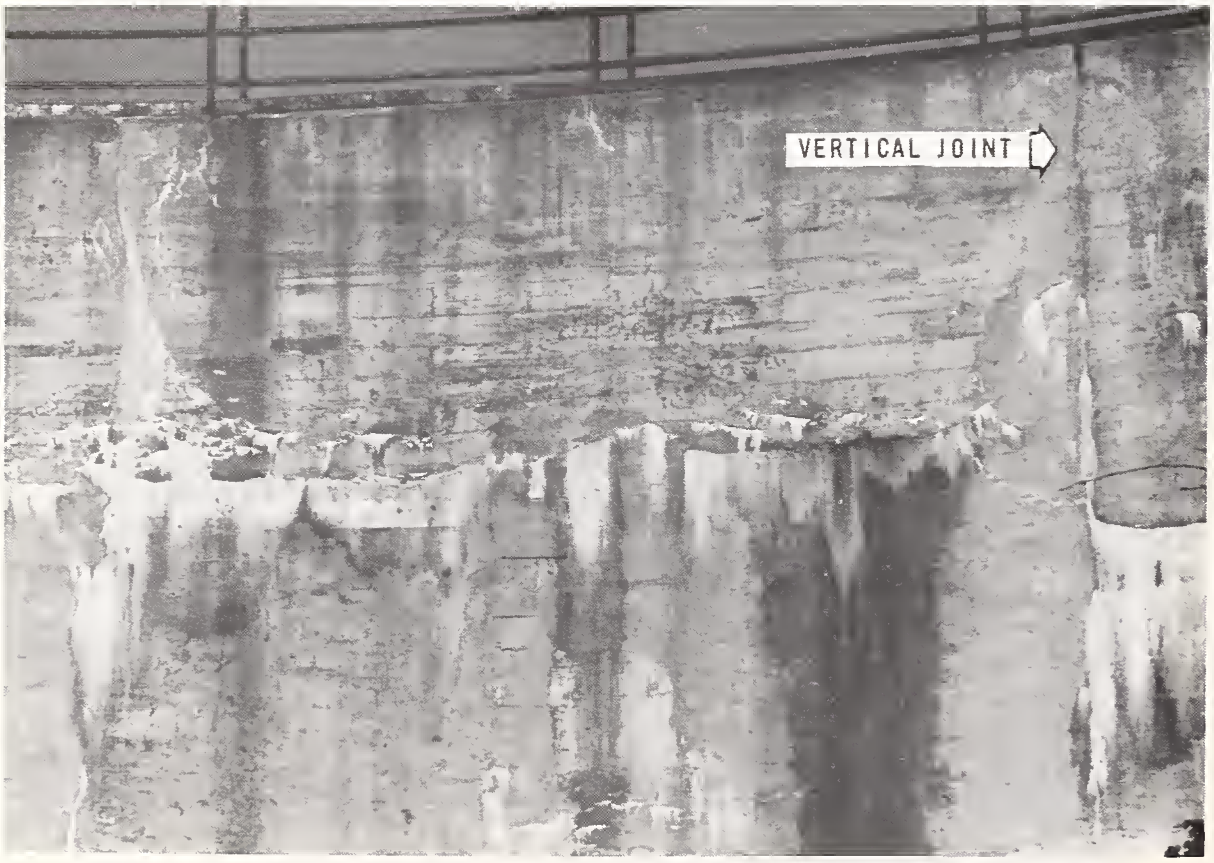


PHOTO 7 JOINT SEEPAGE AT APPROXIMATE NORTH QUARTER POINT.
NOTE: VERTICAL CONTRACTION JOINT.

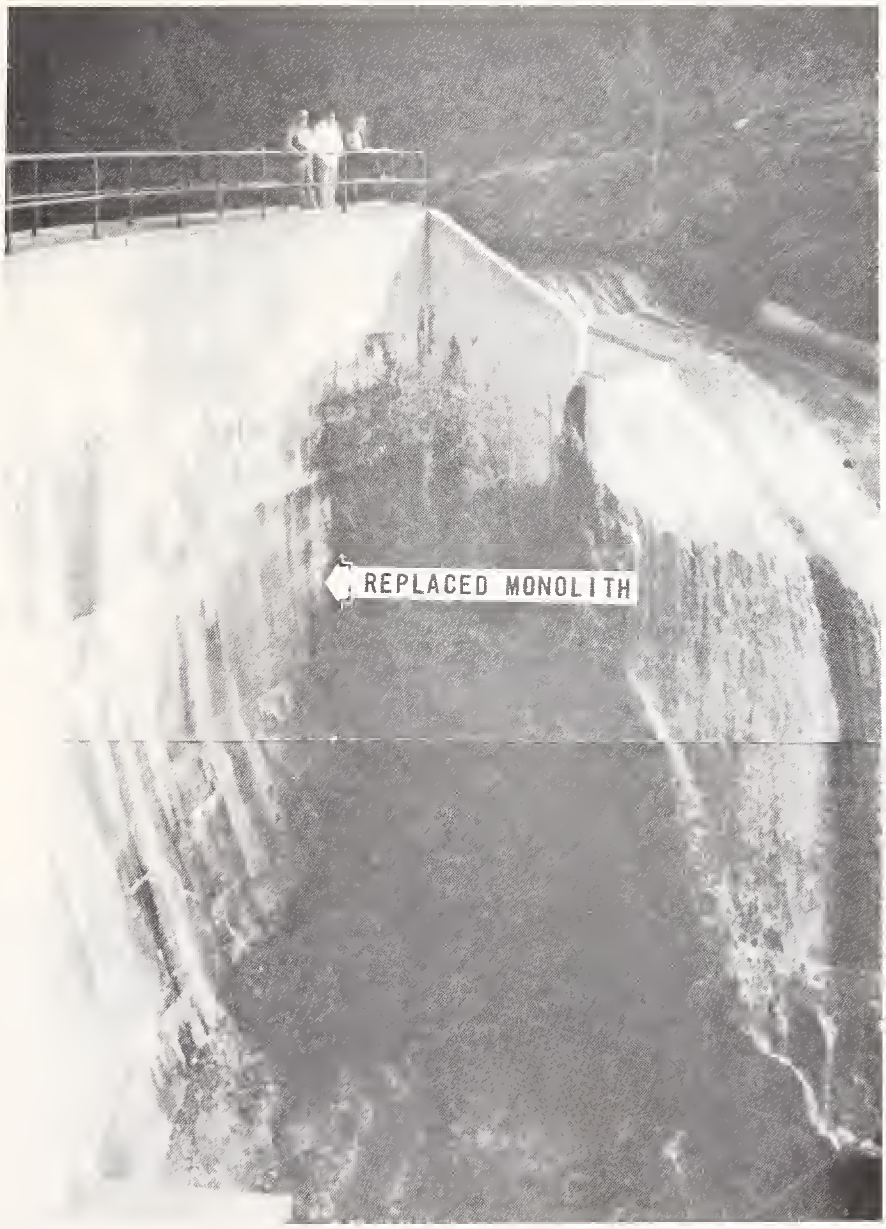


PHOTO 8 NORTH FACE OF DAM, AREA OF REPLACED MONOLITH

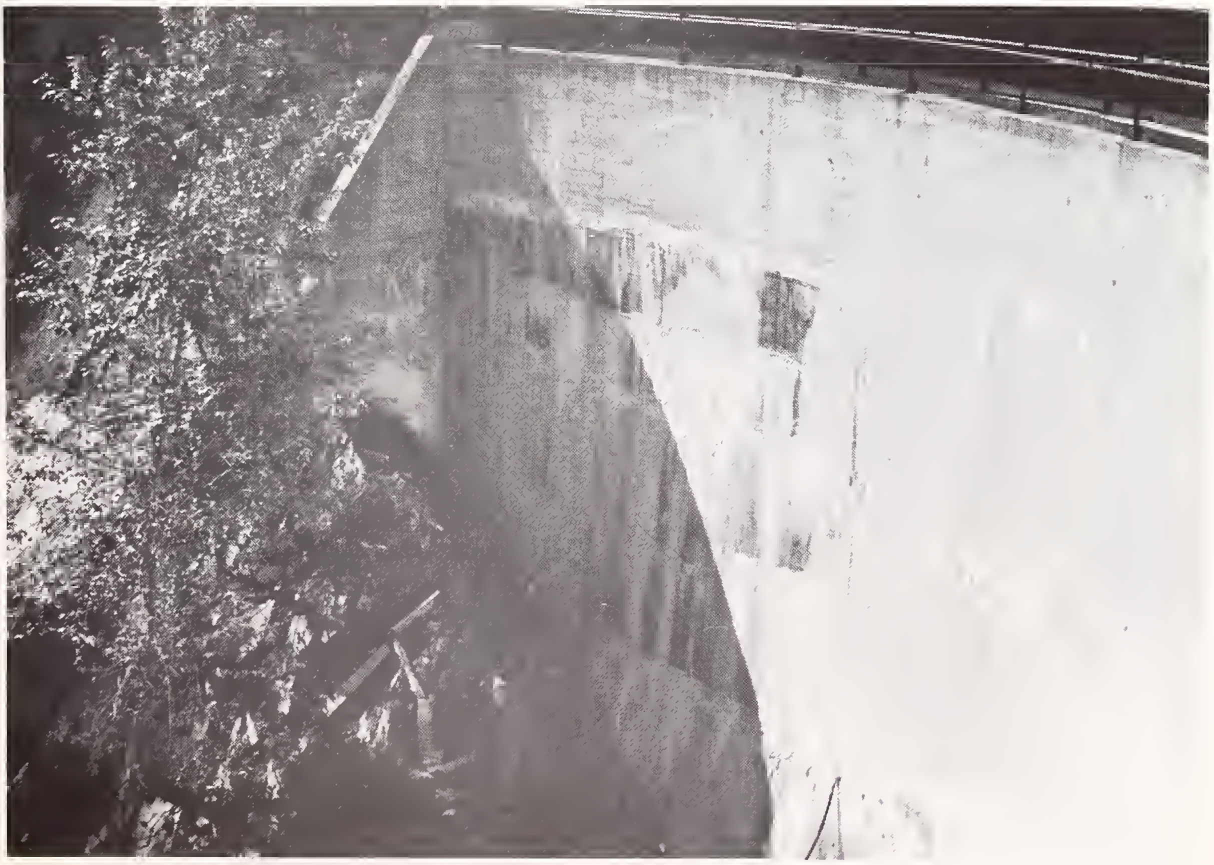


PHOTO 9 SOUTH FACE OF DAM. NOTE: JOINT SEEPAGE.

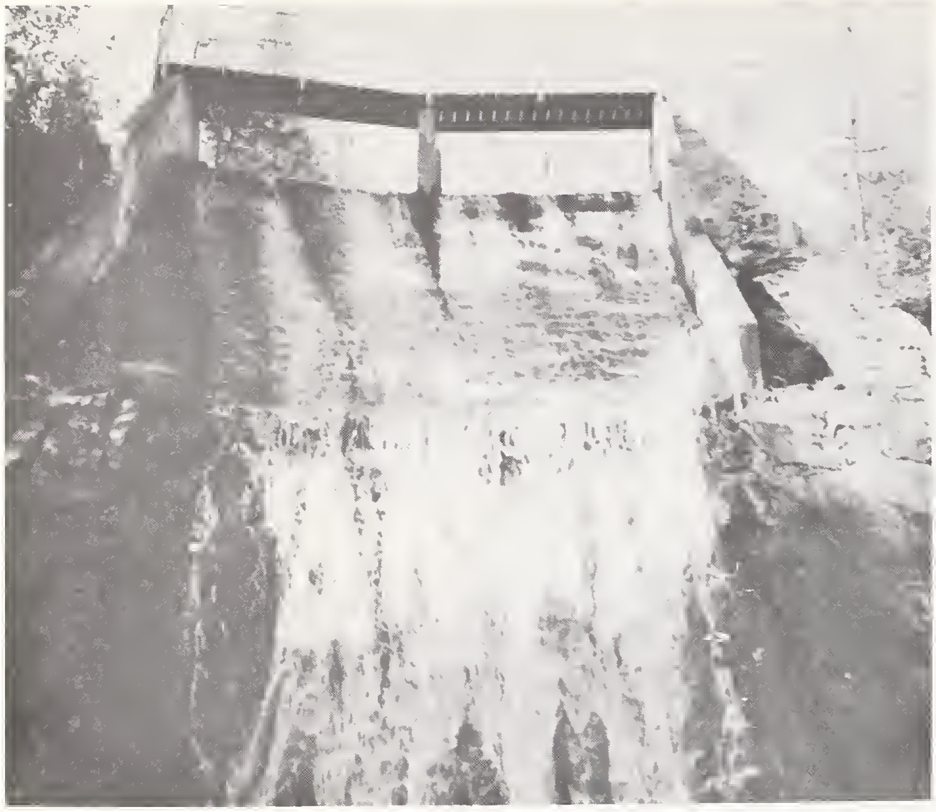


PHOTO 11 SOUTH SPILLWAY CHUTE

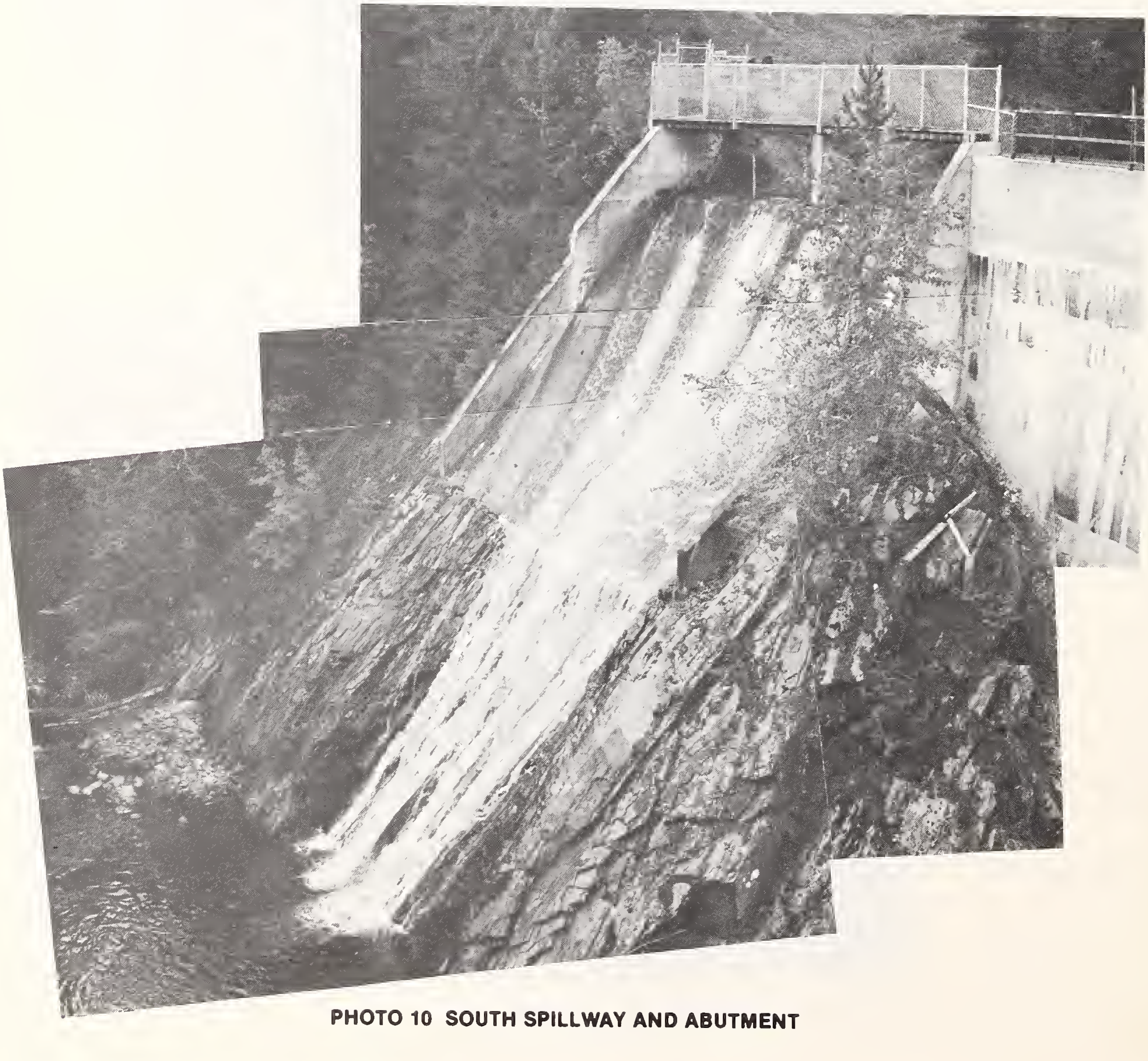


PHOTO 10 SOUTH SPILLWAY AND ABUTMENT

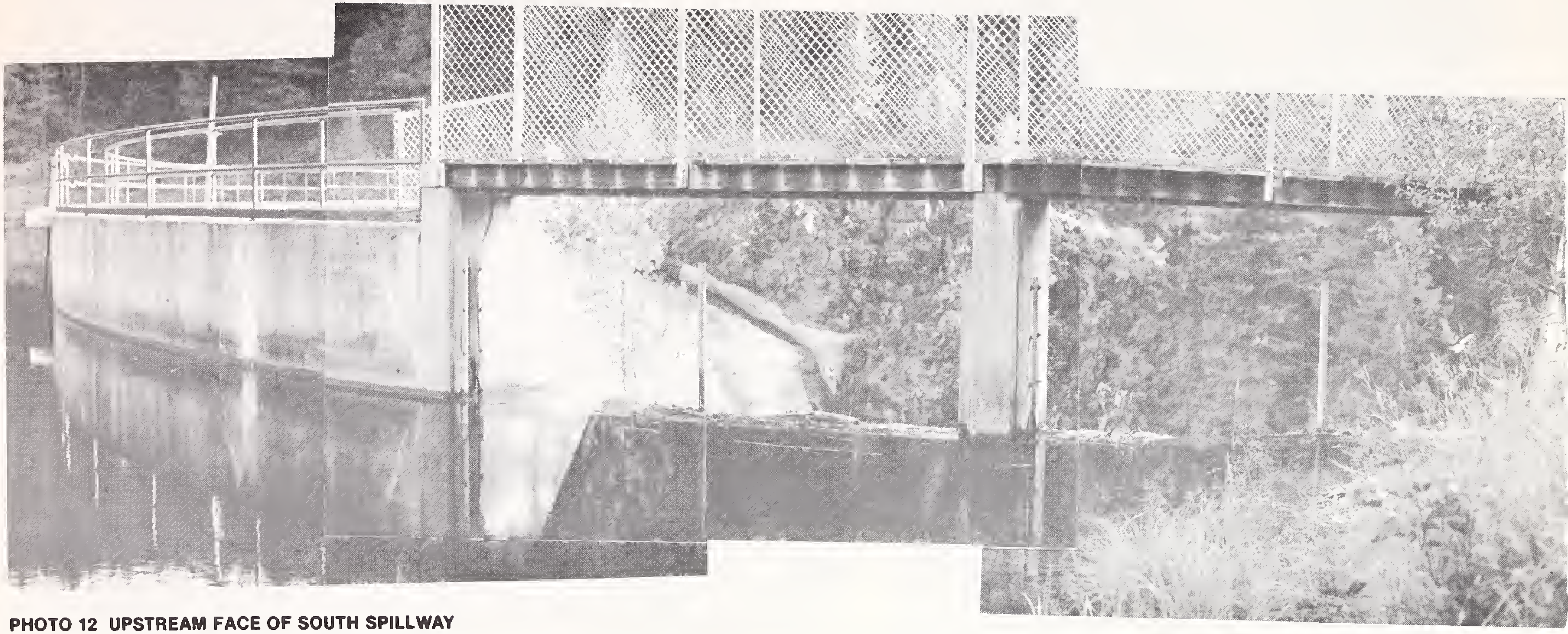


PHOTO 12 UPSTREAM FACE OF SOUTH SPILLWAY

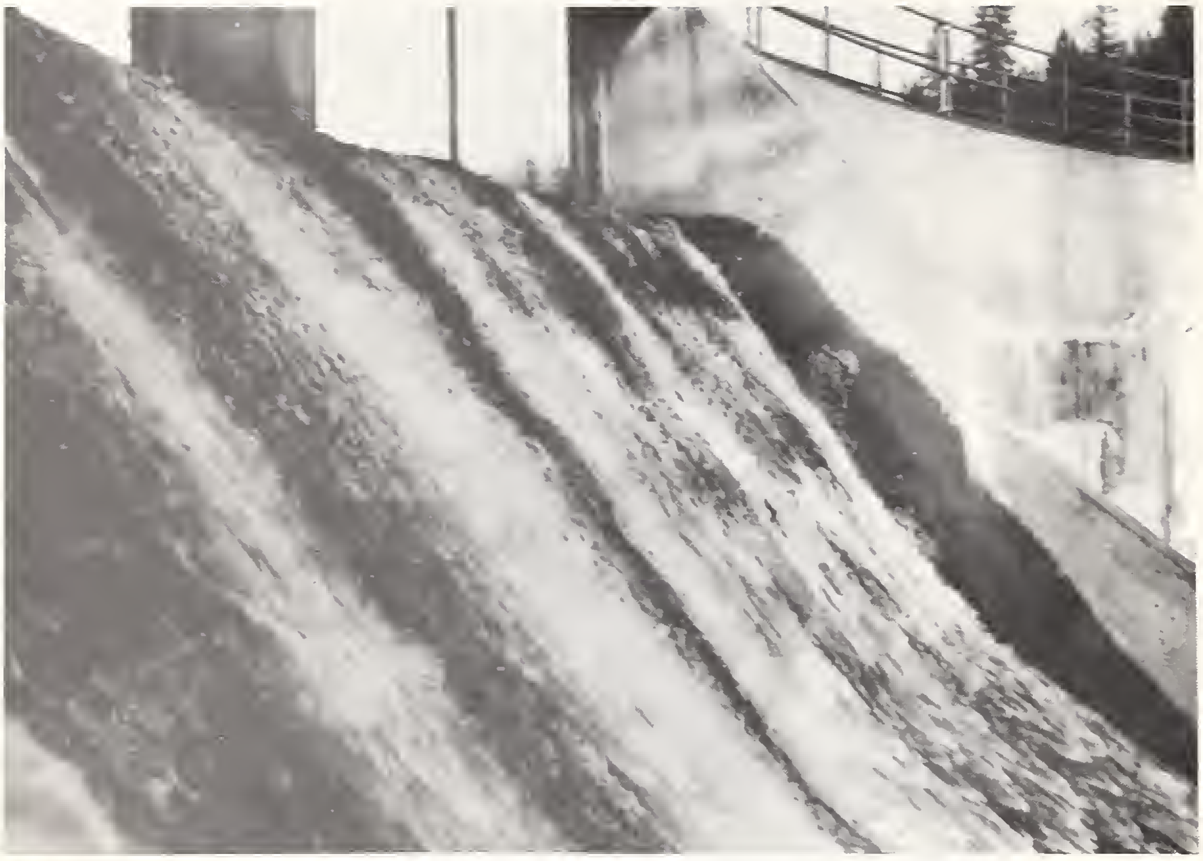


PHOTO 13 SOUTH SPILLWAY — SPALL ON INSIDE TRAINING WALL

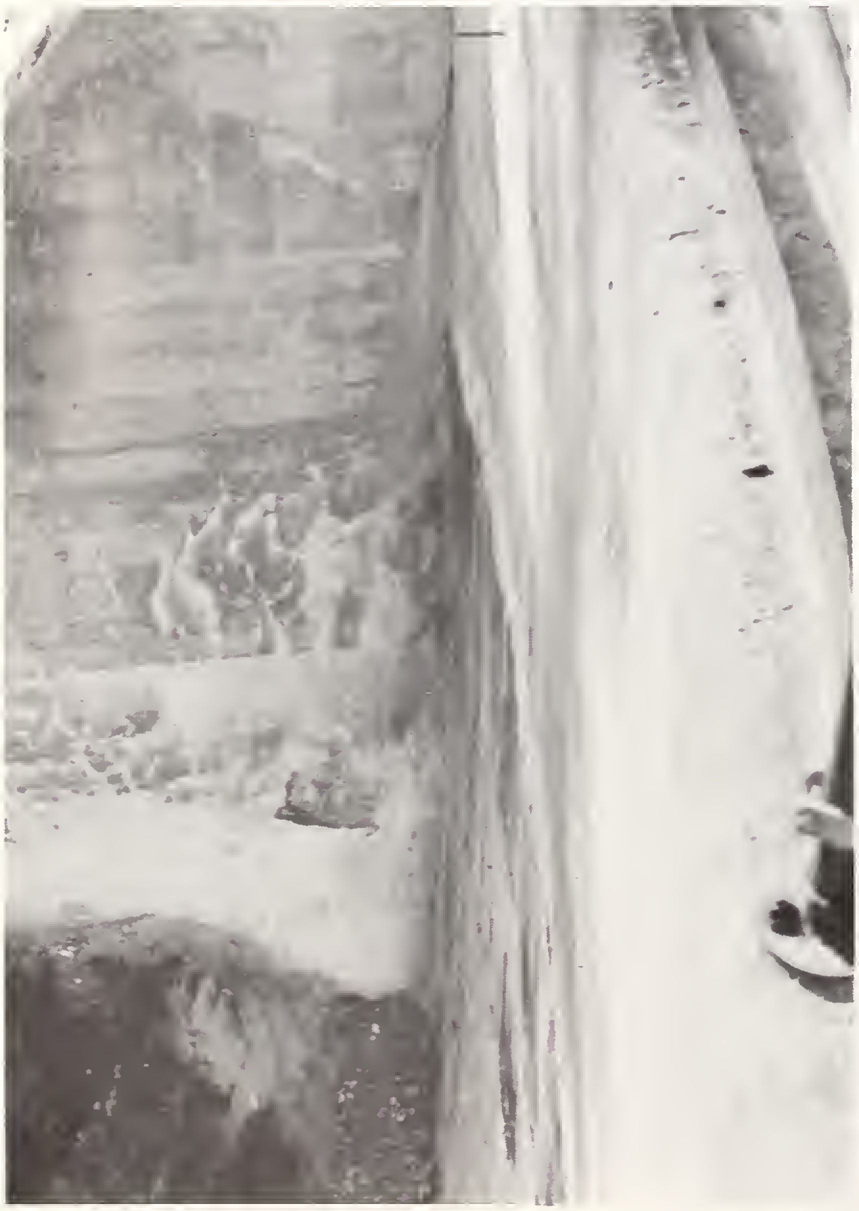


PHOTO 14 SOUTH SPILLWAY — SPALLING OF PATCHED AREA, NEAR OUTSIDE BASE OF TRAINING WALL.

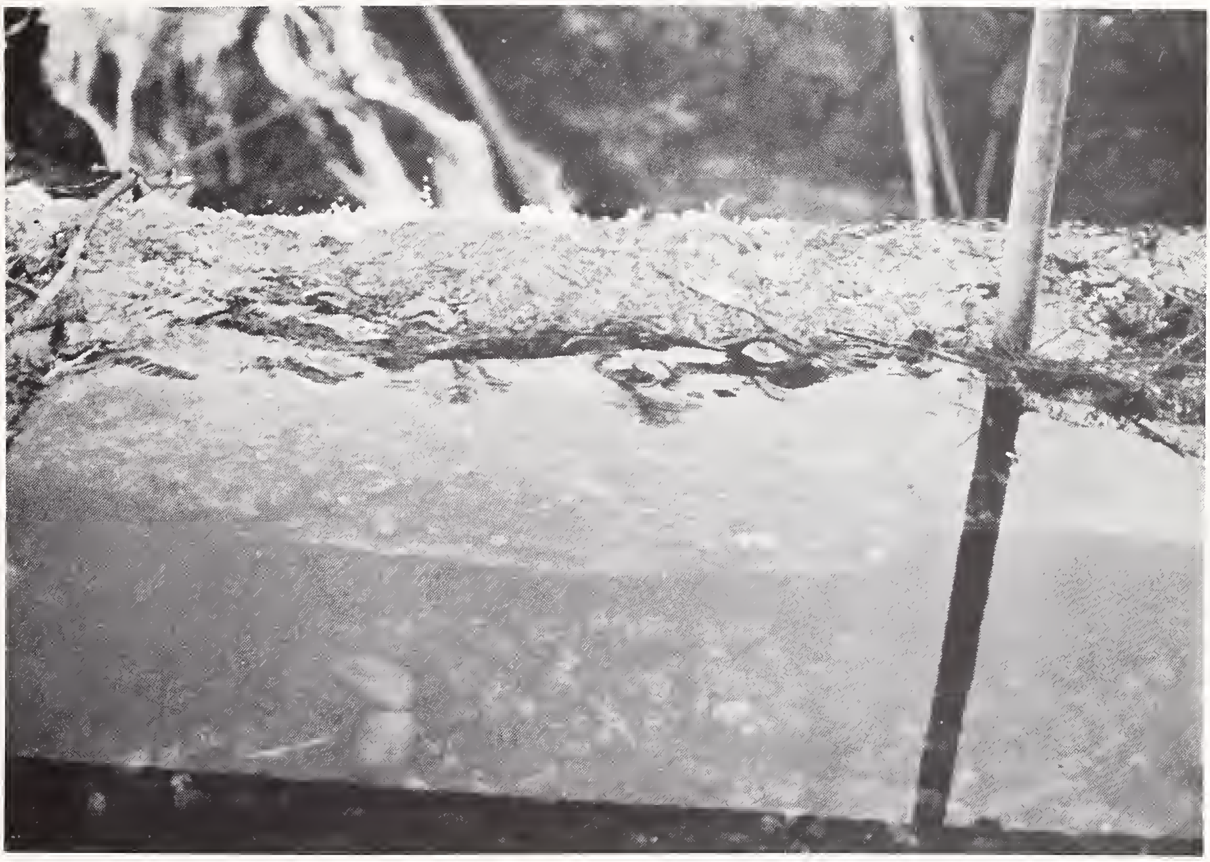


PHOTO 15 SOUTH SPILLWAY SILL

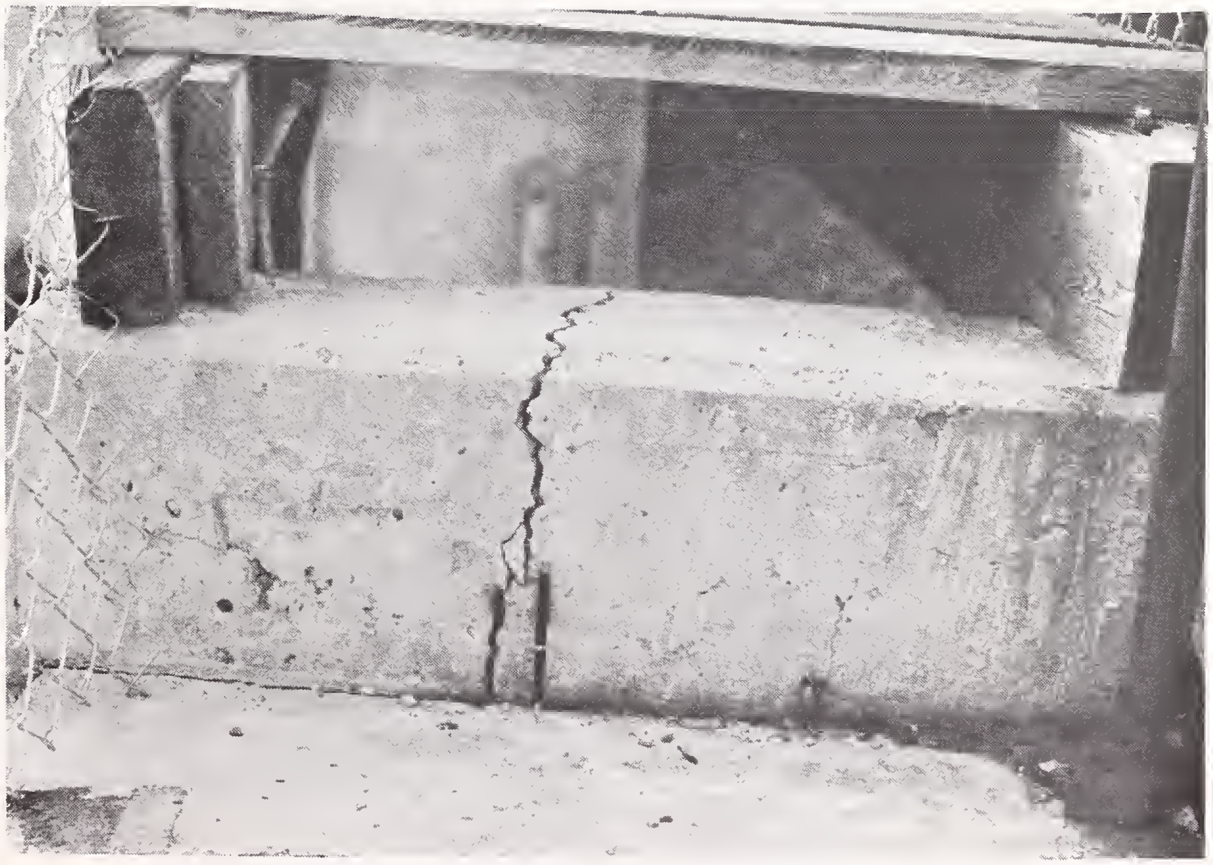


PHOTO 16 CRACK IN SOUTH SPILLWAY TRAINING WALL AT DAM CREST

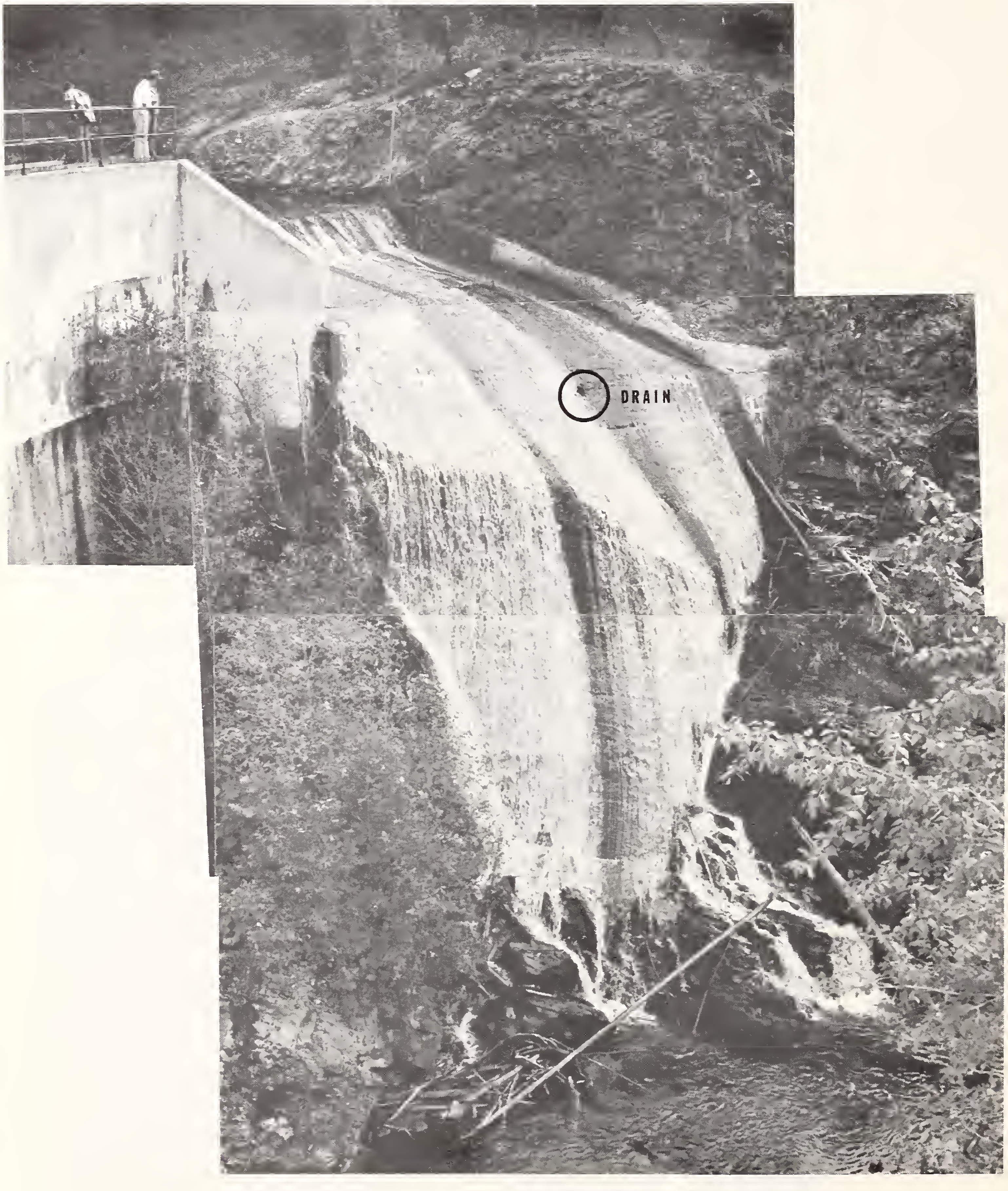


PHOTO 17 NORTH SPILLWAY AND ABUTMENT

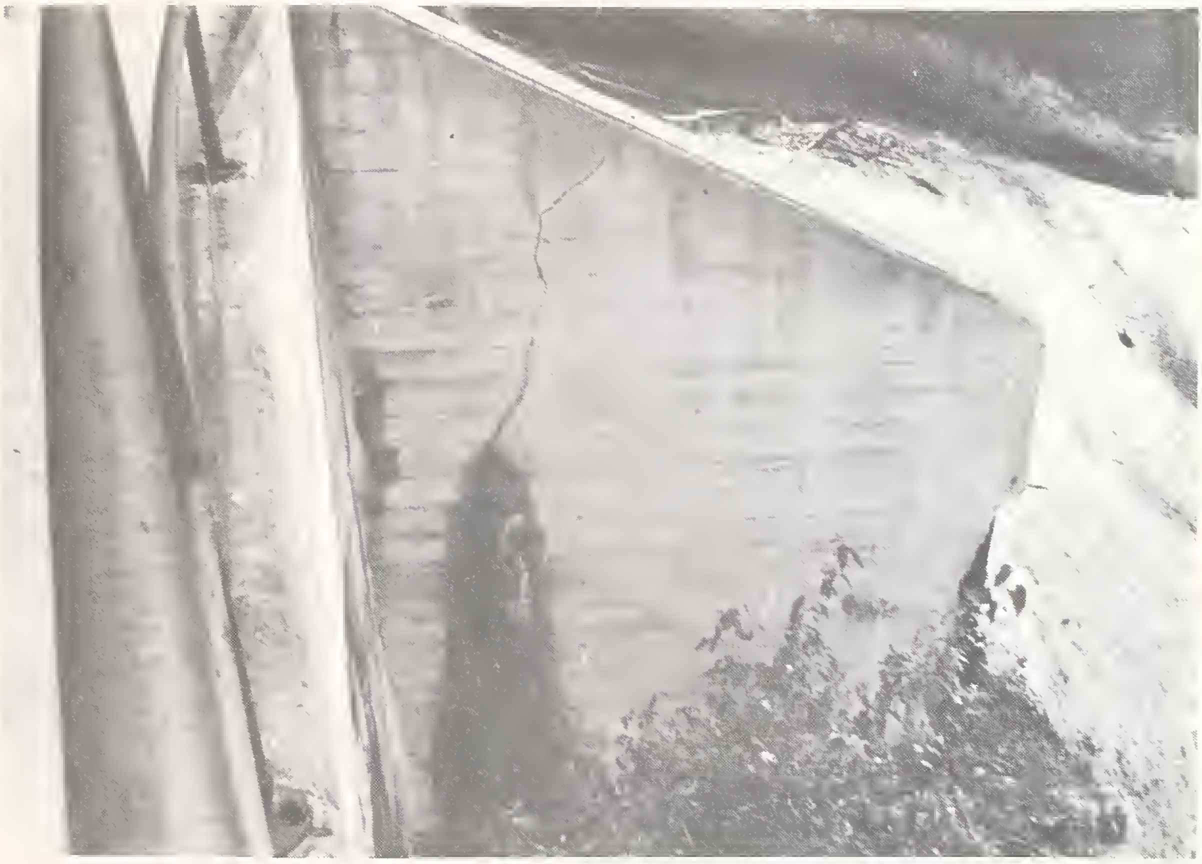


PHOTO 18 NORTH SPILLWAY WING WALL

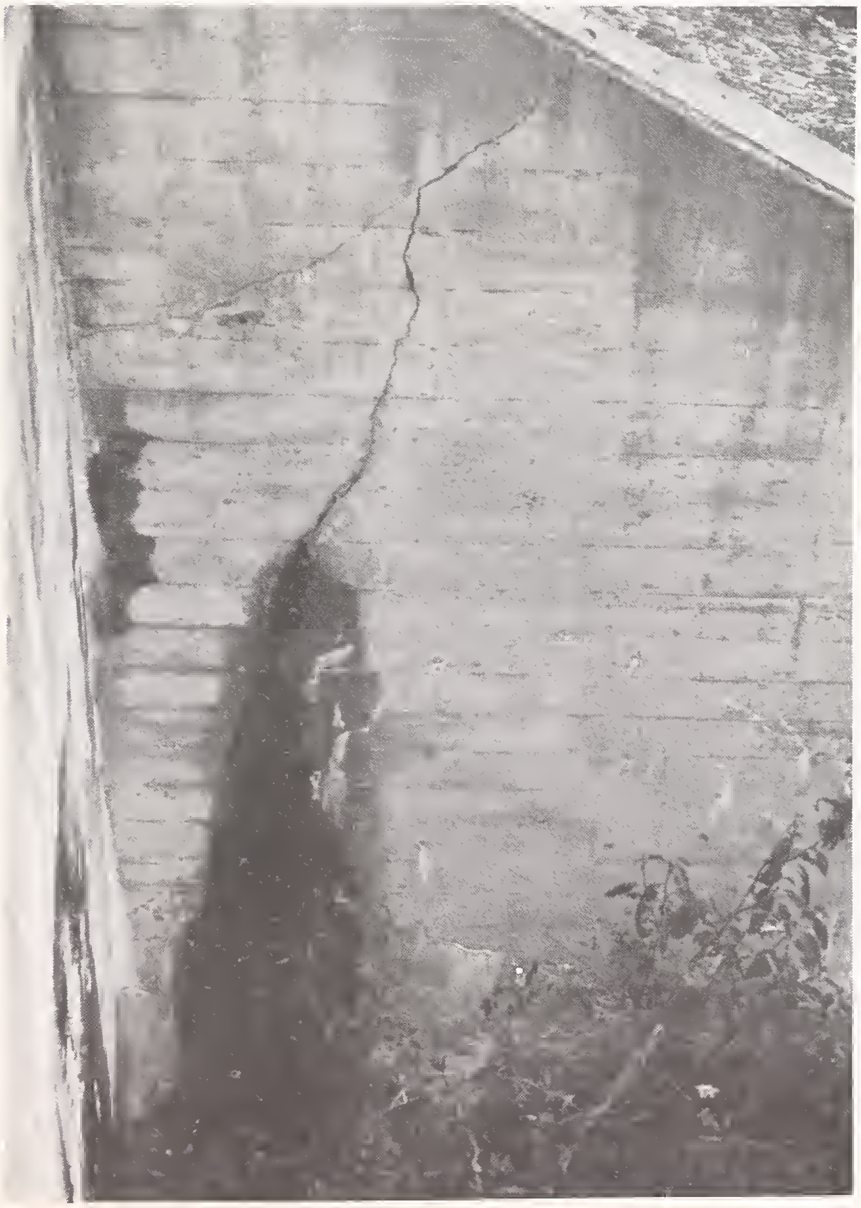


PHOTO 19 CRACK IN NORTH SPILLWAY WING WALL

PHOTO 20 NORTH SPILLWAY SILL

PHOTO 21 OUTLET VALVE HOUSE AND DIVERSION OPENING

PHOTO 22 SLIDE GATE CONTROL

PHOTO 23 DIVERSION OPENING

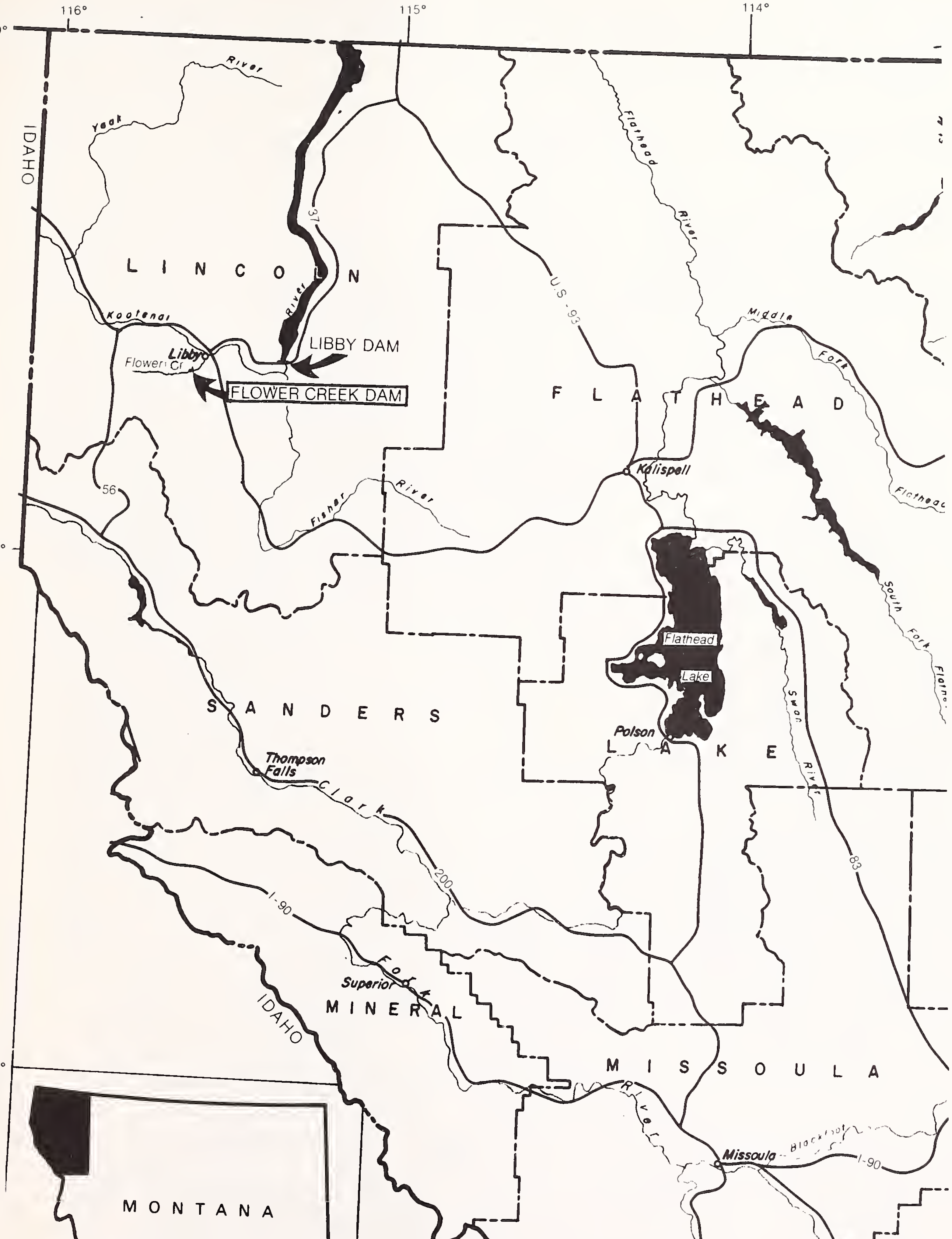


PLATE 1 FLOWER CREEK VICINITY MAP

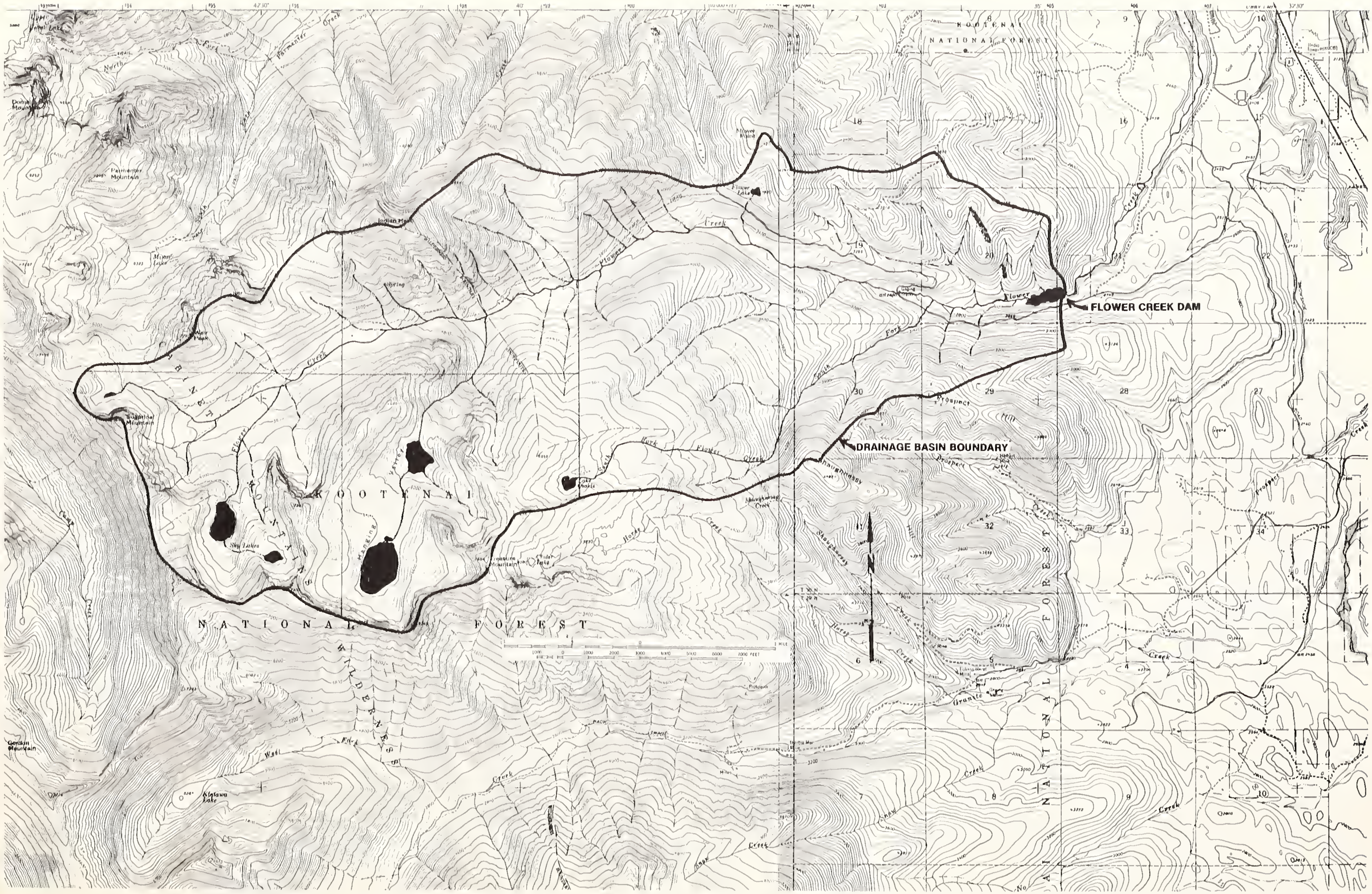


PLATE 2 DRAINAGE BASIN MAP

STAGE - STORAGE CURVE
Flower Creek Dam

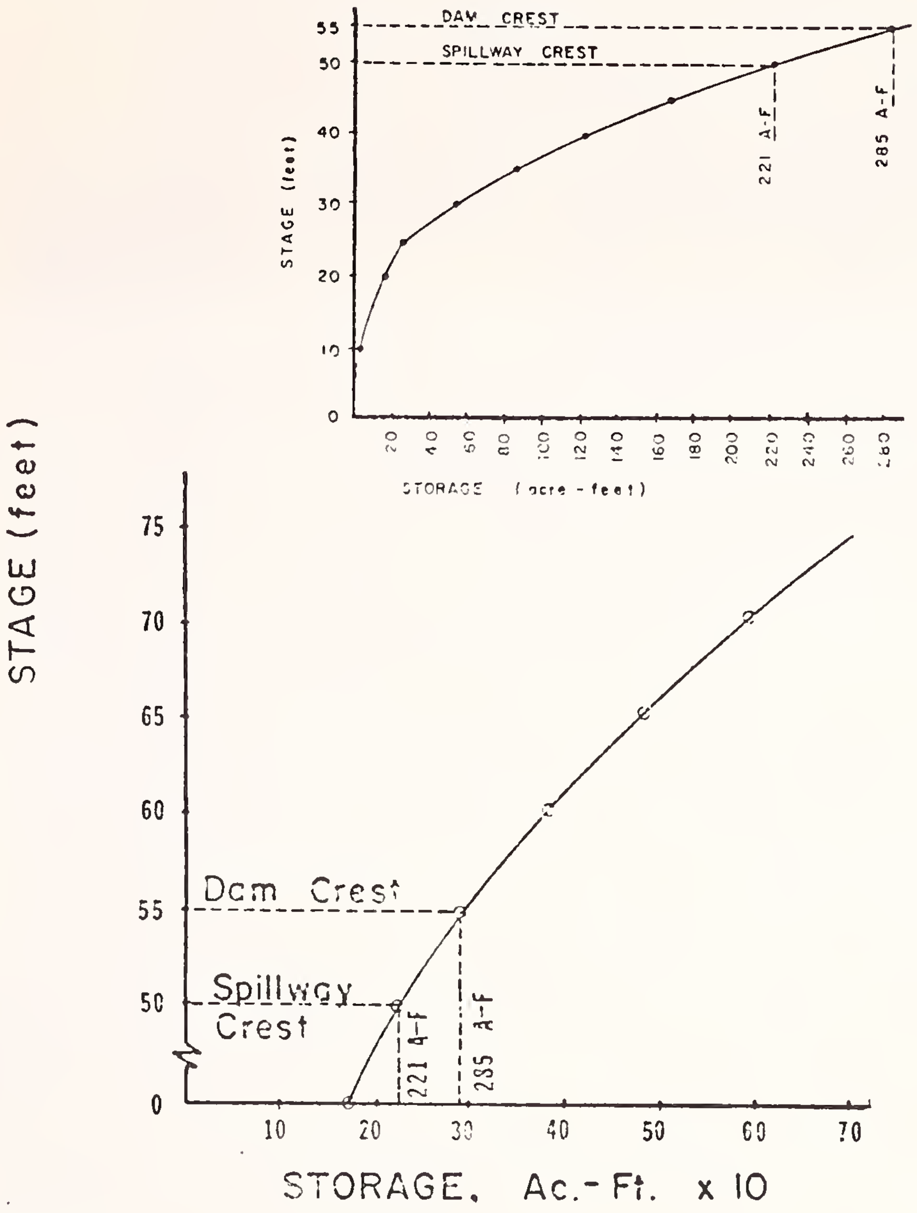


PLATE 3

DISCHARGE RATING CURVE
Flower Creek Dam

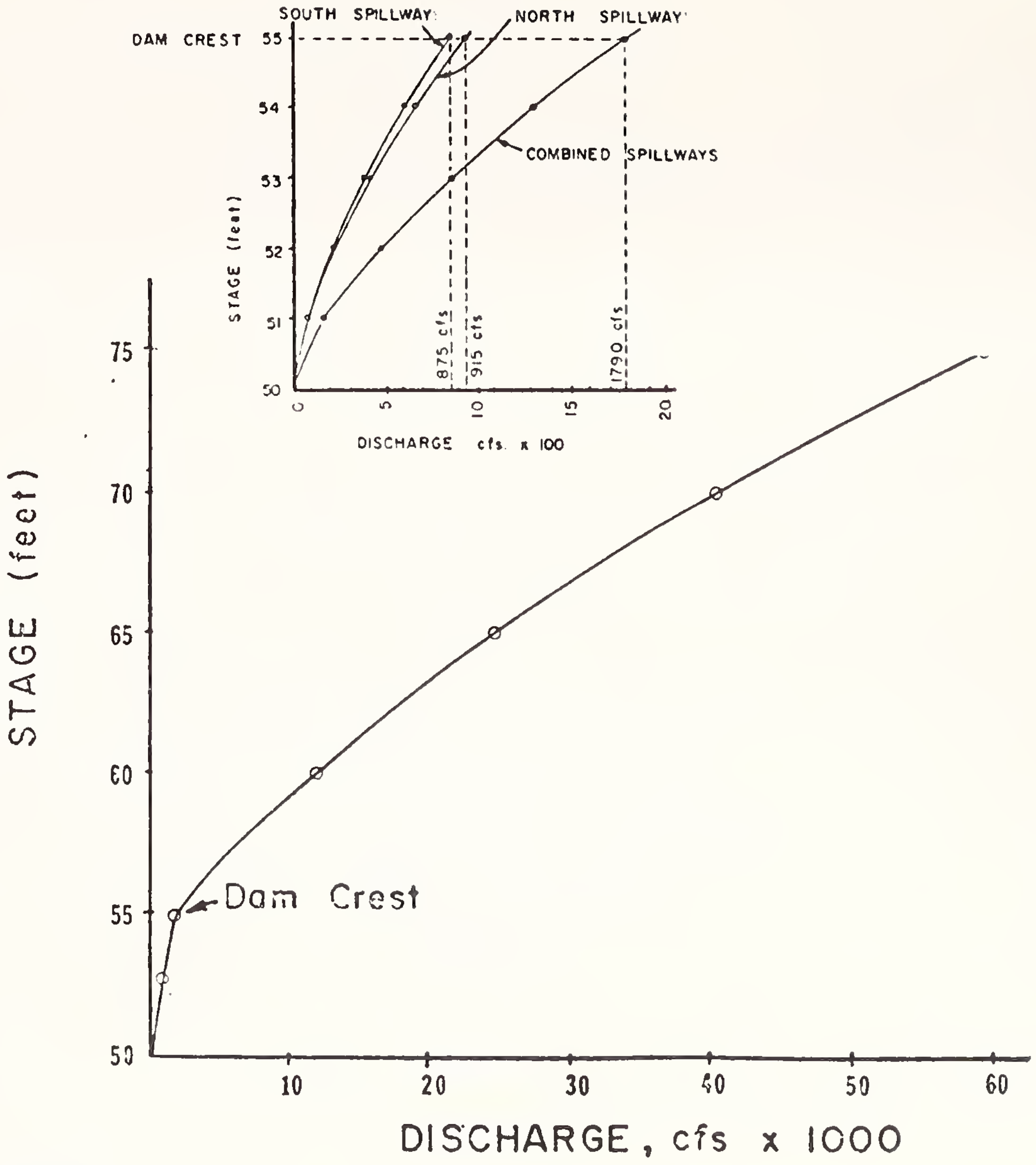
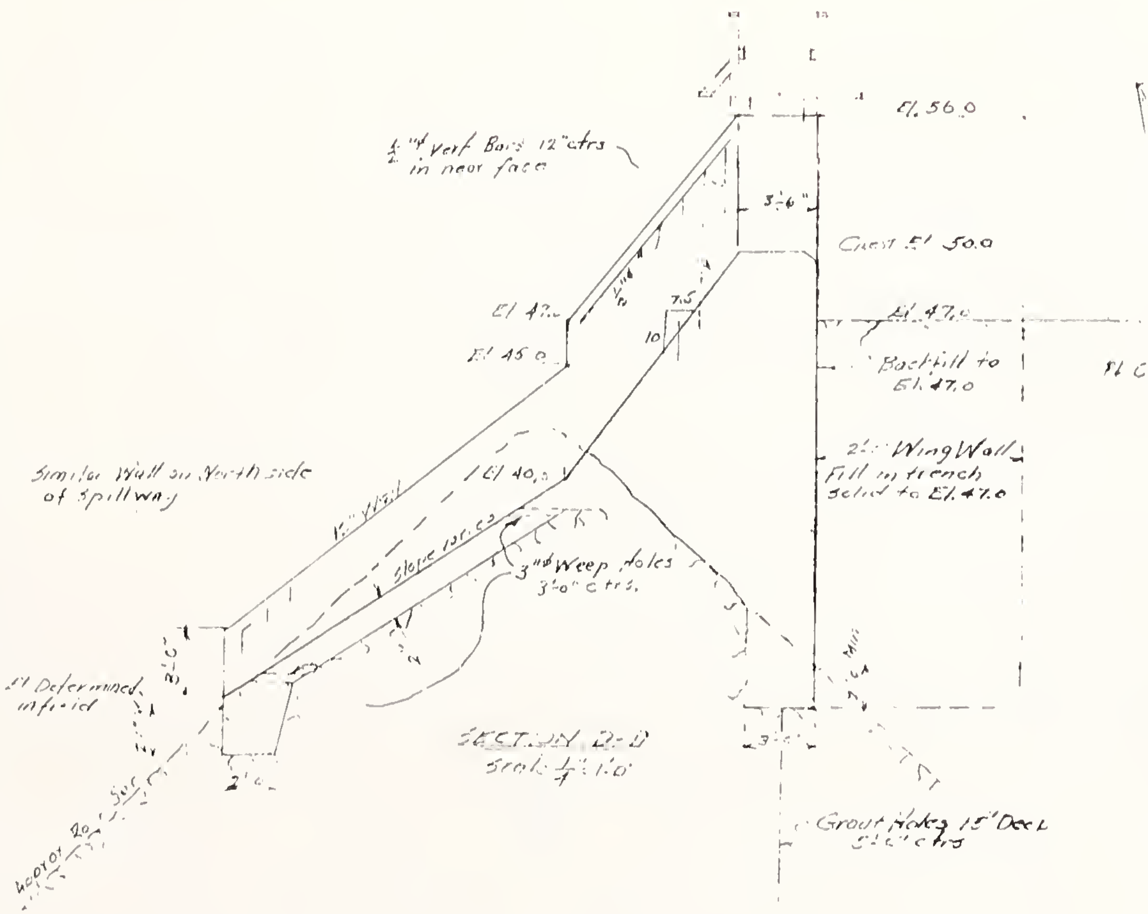


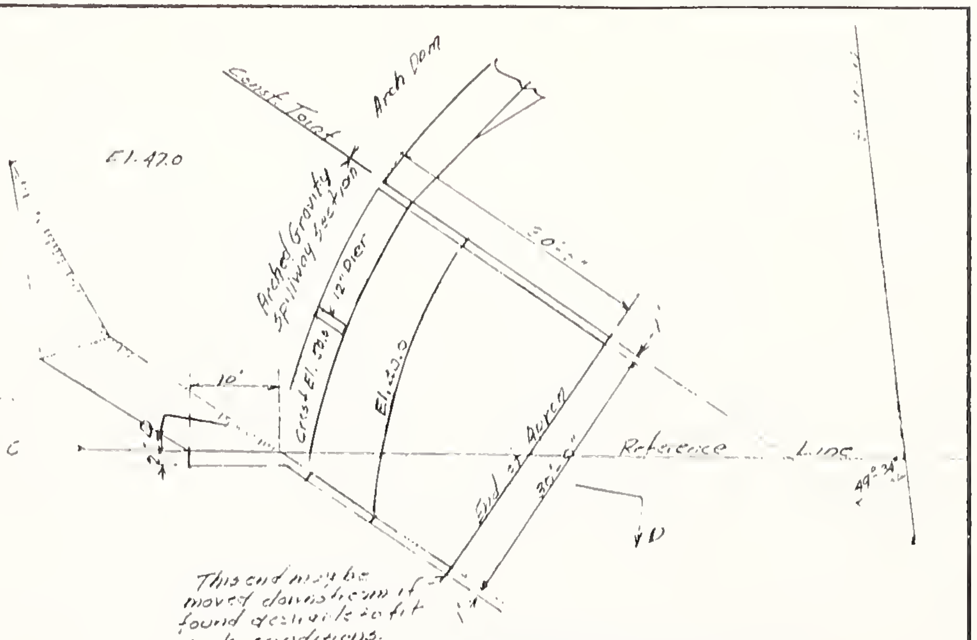
PLATE 4

PLATE 5

B-43052


El. 56.0
1/2"⌀ Vert. Bars 12" ctrs in near face
3'-6"
Crest El 50.0
El 47.0
El 45.0
7.5
10
El. 47.0
Backfill to El. 47.0
2' WingWall
Fill in trench select to El. 47.0
Similar Wall on North side of Spillway
El 40.0
Slope 1st:1.25
3"⌀ Weep Holes 3'-0" ctrs.
3'-0"
As Determined in field
2'-0"
3'-0"
Grout Holes 15' Deep 5'-0" ctrs

SECTION D-D
Scale 1/4" = 1'-0"



This end may be moved downstream if found desirable to fit rock conditions.

PLAN OF SOUTH SPILLWAY
Scale 1" = 10'

References:-
Details & Additional Sections - A42735
Plan, Elevations & Sections - A42996

NOTE: Details of South Spillway shown on this Drawing supersede those on A-42996

REDUCED TO 36.5% OF ORIGINAL

Public Utility Engineering & Service Corporation — CHICAGO

MOUNTAIN STATES POWER CO LIBBY, MONT. WATER SUPPLY SYSTEM-1945 AUTH.						FLOWER CREEK STORAGE RESERVOIR PLAN & SECTION OF SOUTH SPILLWAY DAM		
J	F	C		DRAWN BY JW	TRACED BY	SCALE As Shown	PROJECT NUMBER 1211-007	
H	E	B		CHECKED BY		DATE 8-7-45	No. B 43052	
G	D	A		APPROVED J. Webster				

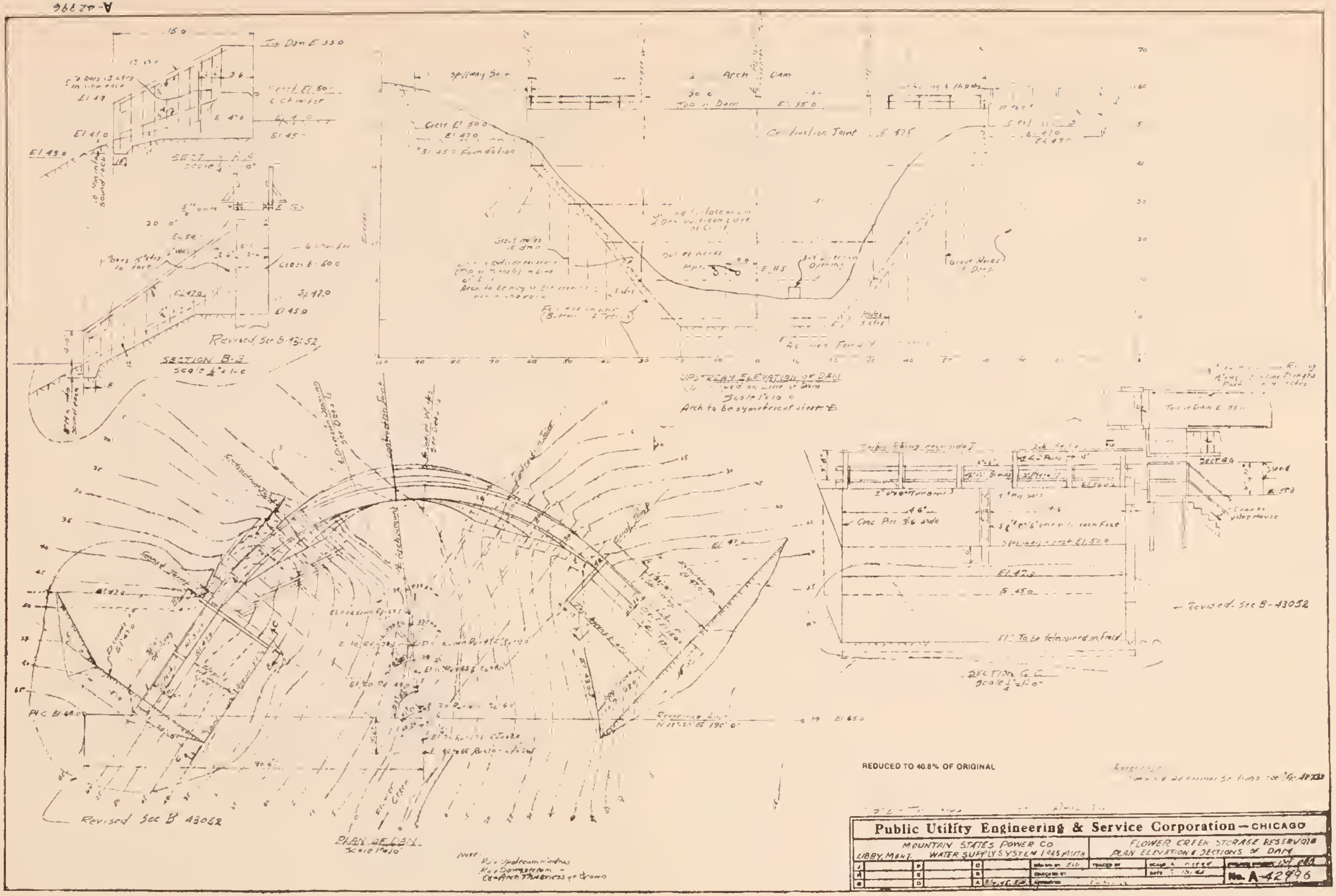
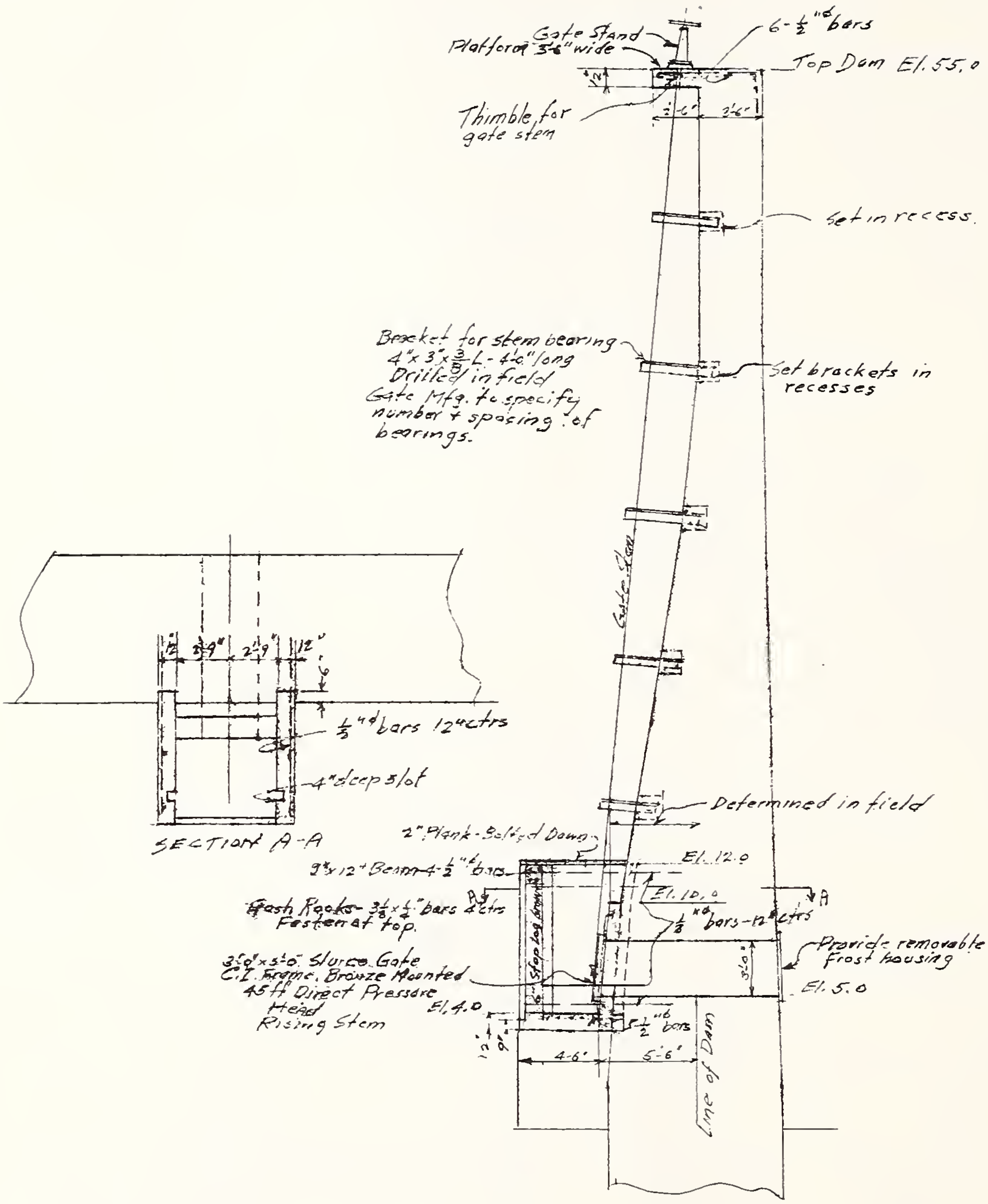

A-42996
SECTION B-B
Scale 1/4"=1'-0"
Revised See B-43052
Top Dam El 55.0
Crest El 50.0
El 45.0
El 43.0
UPSTREAM ELEVATION OF DAM
Scale 1"=10'-0"
Arch to be symmetrical about ℄
Arch Dam
Top of Dam El 55.0
Construction Joint
Crest El 50.0
El 47.0
El 45.0 Foundation
Grout Holes
SECTION C-C
Scale 1/4"=1'-0"
Revised See B-43052
Conc Pier 3'-6" wide
El 42.0
El 45.0
Top of Dam El 55.0
Reference Line
El 65.0
PLAN OF DAM
Scale 1"=10'
Flower Creek
Revised See B 43062
Note:
Ru = Upstream Radius
Rd = Downstream
Ce = Arch Thickness at crown
REDUCED TO 40.8% OF ORIGINAL
Public Utility Engineering & Service Corporation — CHICAGO
MOUNTAIN STATES POWER CO
LIBBY, MONT. WATER SUPPLY SYSTEM 1945 AUTH
FLOWER CREEK STORAGE RESERVOIR
PLAN ELEVATION & SECTIONS OF DAM
No. A-42996

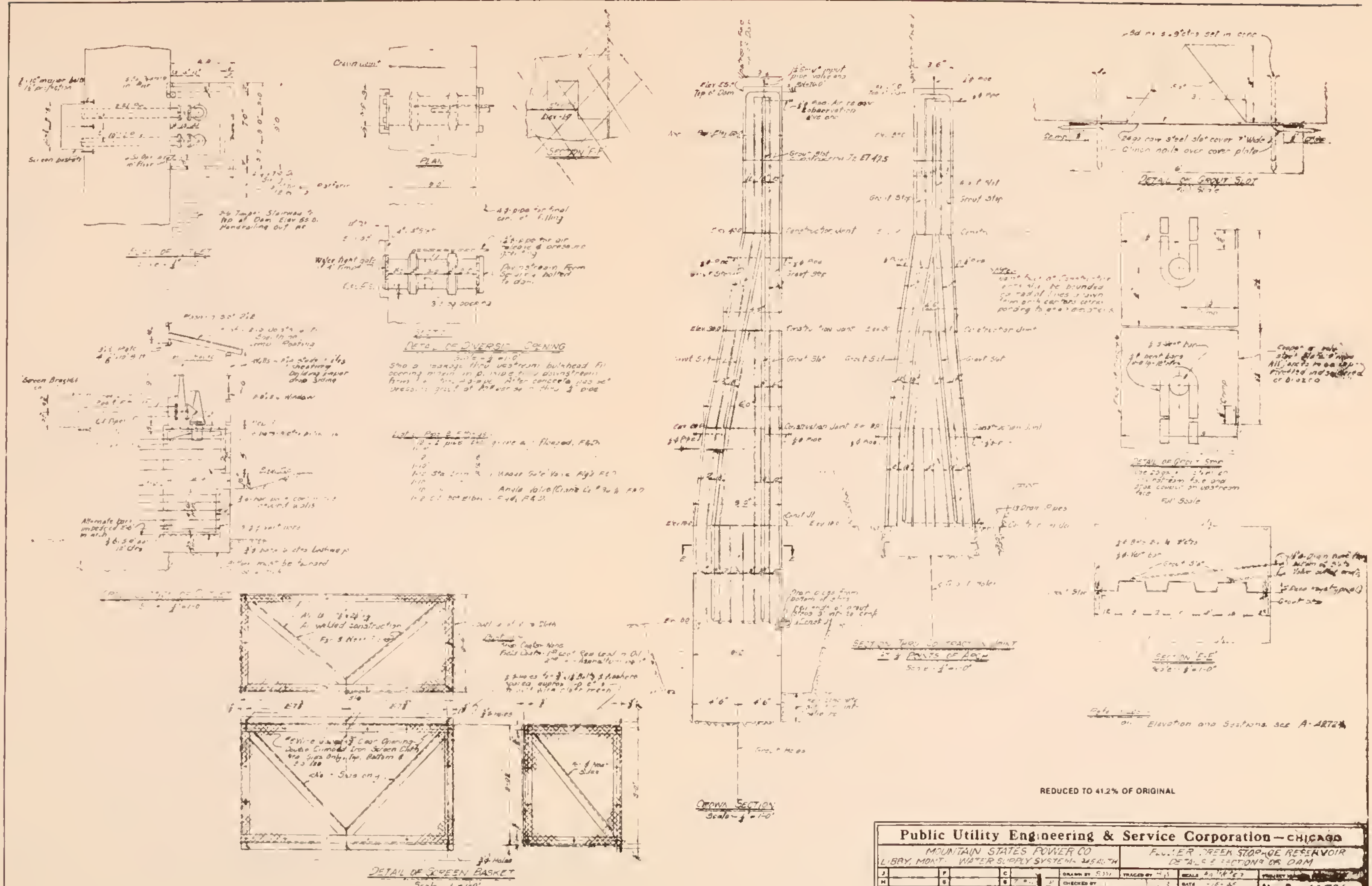
PLATE 6



SKETCH "A"
FLOWER CREEK RESERVOIR DAM
SLUICE GATE OUTLET
Scale ¼" = 1'-0"
CFE 12-11-007
[illegible] Corp
Chicago 8/13/45

REDUCED TO 37.3% OF ORIGINAL

PLATE 7



REDUCED TO 41.2% OF ORIGINAL

PLATE 8

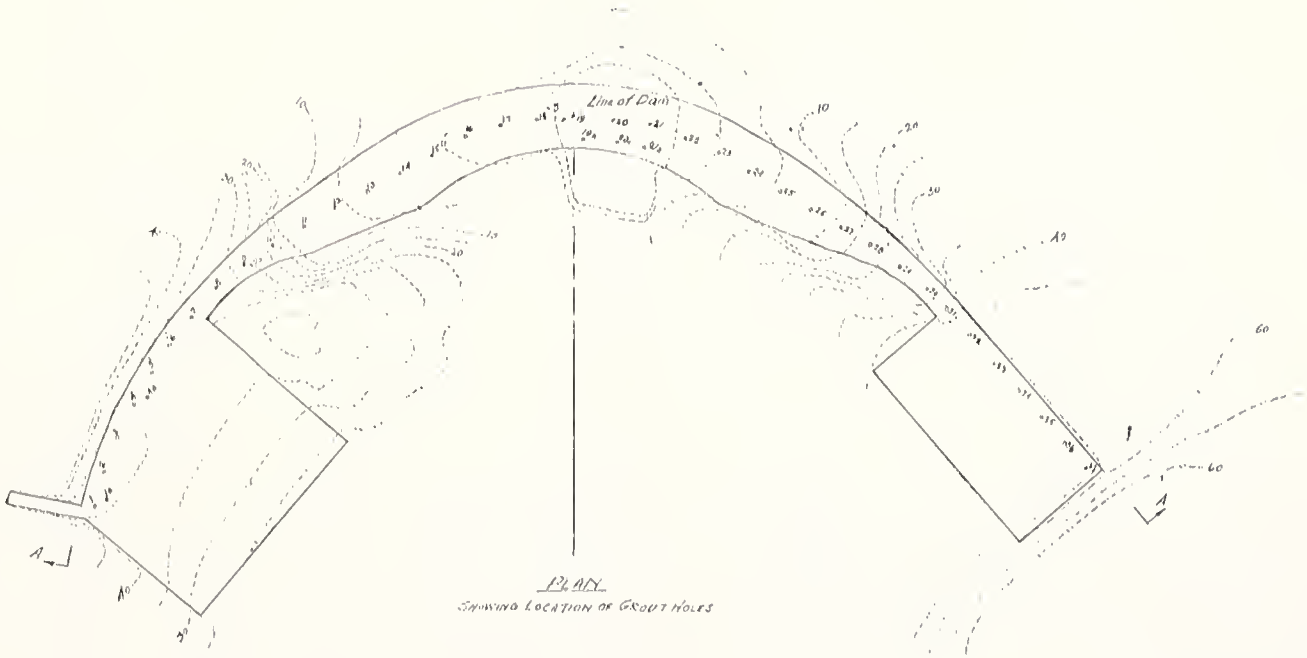
Public Utility Engineering & Service Corporation — CHICAGO

MOUNTAIN STATES POWER CO
LIBBY, MONT. WATER SUPPLY SYSTEM

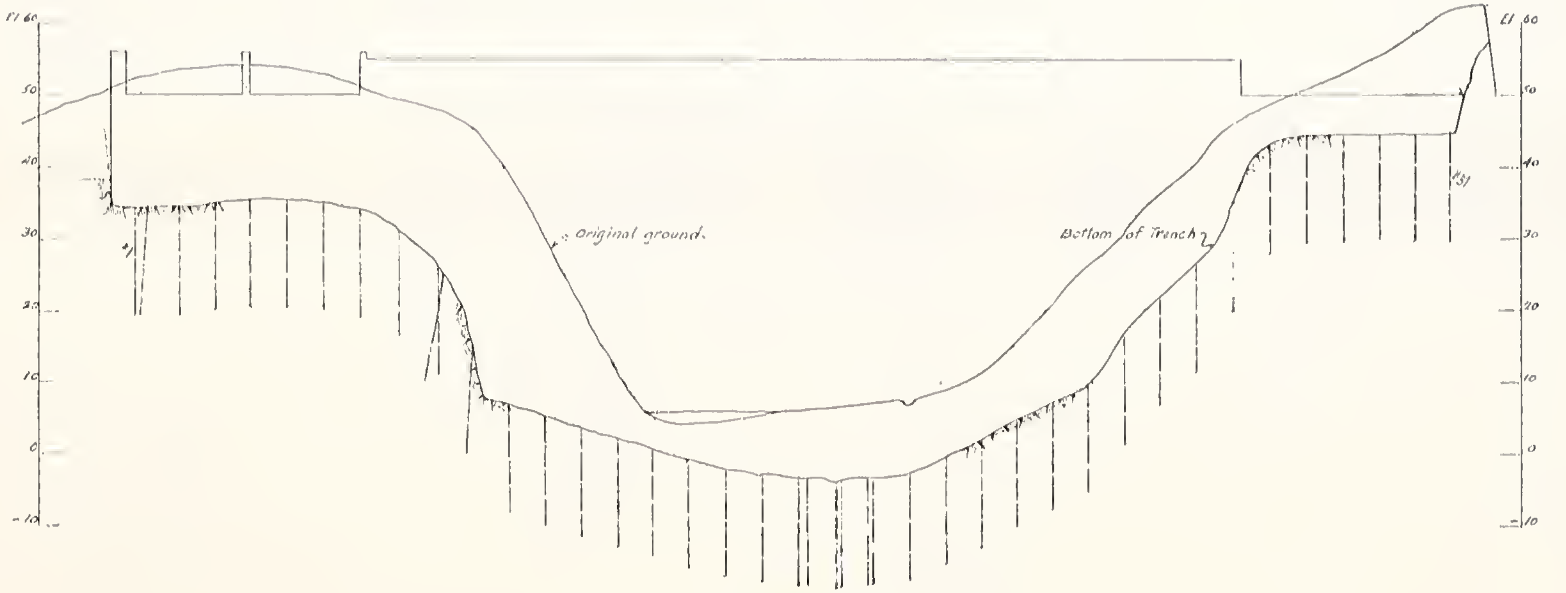
FLOWER CREEK STORAGE RESERVOIR
DETAILS & SECTIONS OF DAM

No. A 42735

PLATE 9



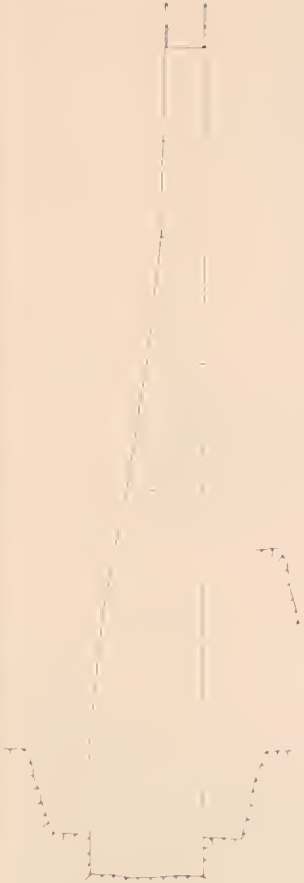
PLAN
SHOWING LOCATION OF GROUT HOLES



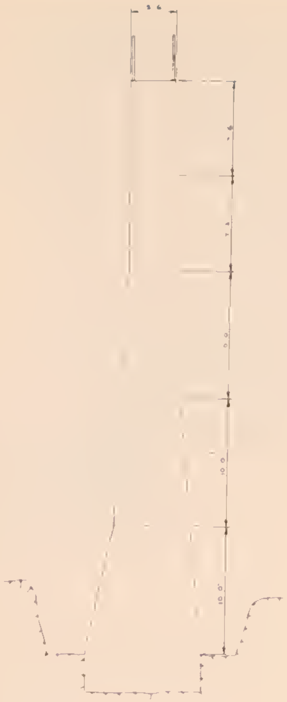
SEC. A-A.
DEVELOPED ON LINE OF DAM.
SCALE : 1" = 10'

LIBBY, MONTANA. RESERVOIR
MOUNTAIN STATES POWER CO
FOUNDATION GROUTING
MIDLAND CONSTRUCTORS, INC.
D2-3 NOV. 26, 45 J.K.J.

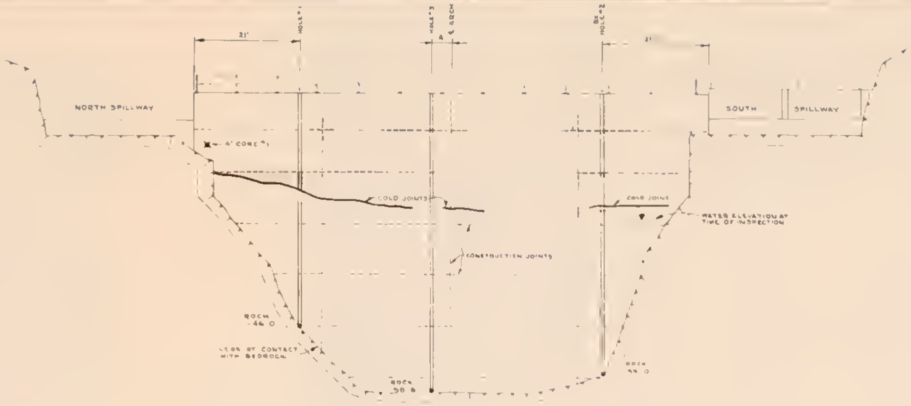
REDUCED TO 38.2% OF ORIGINAL



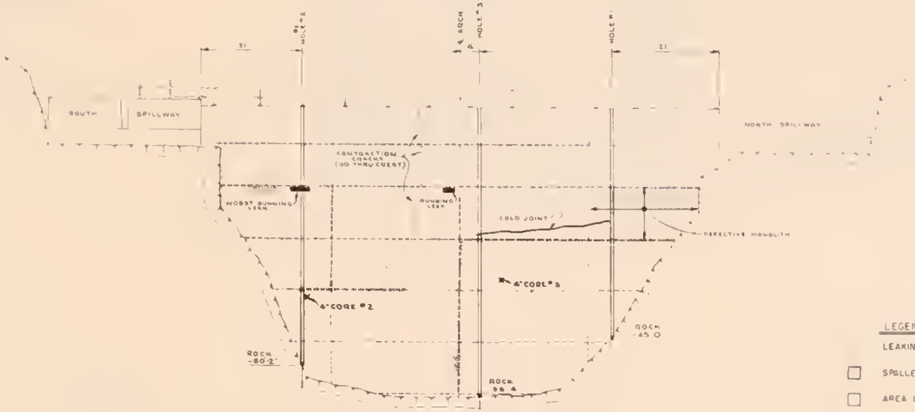
CROWN SECTION
SCALE: 1/4"=1'-0"



SECTION AT 1/4 POINTS OF ARCH
SCALE: 1/4"=1'-0"



UPSTREAM ELEVATION
SCALE: 1"=10'-0"



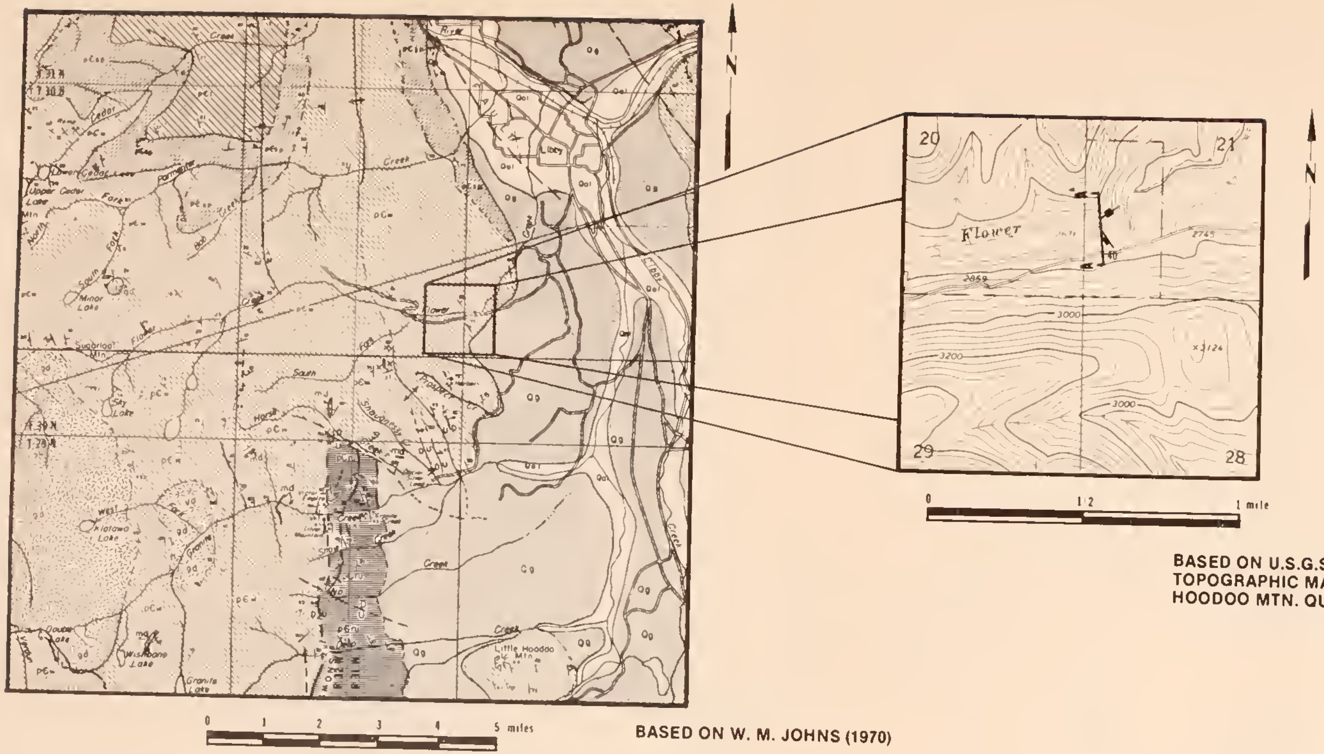
DOWNSTREAM ELEVATION
SCALE: 1"=10'-0"

LEGEND
LEAKING JOINTS
☐ SPALLED CONCRETE
☐ AREA COVERED BY LIME

REDUCED TO 43.1% OF ORIGINAL

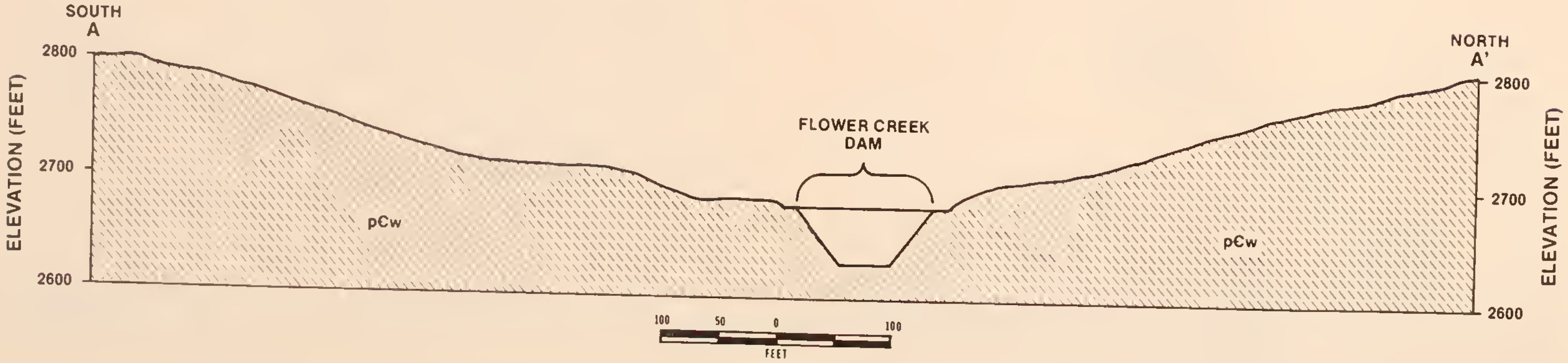
DESIGNED DRAWN L.R.E. CHECKED G.R.M.	APPROVED SCALE AS SHOWN DATE JUNE, 1966 66 P 368 6637	Stevens, Thompson, Runyan & Ries, Inc. Engineers/Planners PORTLAND OREGON SEATTLE WASHINGTON	PACIFIC POWER & LIGHT CO.	FLOWER CREEK DAM PHYSICAL DEFECTS	SHEET 1 / 1

PLATE 10



BASED ON U.S.G.S. 7.5 MINUTE TOPOGRAPHIC MAP: LITTLE HOODOO MTN. QUADRANGLE

BASED ON W. M. JOHNS (1970)



EXPLANATION

Qal

Alluvium

Recent gravel, sand, and silt. Some Pleistocene glacial outwash.

Qg

Quaternary glacial deposits

Undifferentiated lacustrine silt, clay, drift, gravel, and alluvial-fan material.

pЄl

Libby Formation

Light gray, dark gray, green gray, yellow, and yellow green argillite; some calcareous argillite; a few thin beds of yellow and yellow-brown limestone and stromatolitic limestone.

pЄsp

Striped Peak Formation

Gray and grayish-red sericitic quartzite and gray-red-purple argillite. Some interbedded gray-green laminated argillite near center. Ripple-marked and mud-cracked strata common; some casts of salt crystals.

pЄw

Wallace Formation

Gray, green-gray, and yellow calcareous and dolomitic sandy argillite; discontinuous dolomite and magnesian limestone beds are common near the middle of the formation. Grayish-red shale and minor quartzite locally present near the top. Mud cracks and ripple marks common.

pЄru

Ravalli undifferentiated

Magnetite-bearing medium- to light-gray quartzite, quartzitic argillite, and argillite; some interbedded and laminated green-gray quartzitic argillite weathering gray. In the Flathead Lake region grayish-red-purple, grayish-red, and grayish-green argillite and locally calcareous quartzitic greenish-gray argillite. Upper Ravalli marker bed of calcareous argillite mapped as pCr$_1$.

gd

Granitic rocks including granodiorite, quartz monzonite, and alaskite occurring as stocks

md

Metadiorite—dark-green-gray and gray-black dikes, sills, and stocks mapped by others as gabbro, hornblende gabbro, amphibolite, and metadiorite

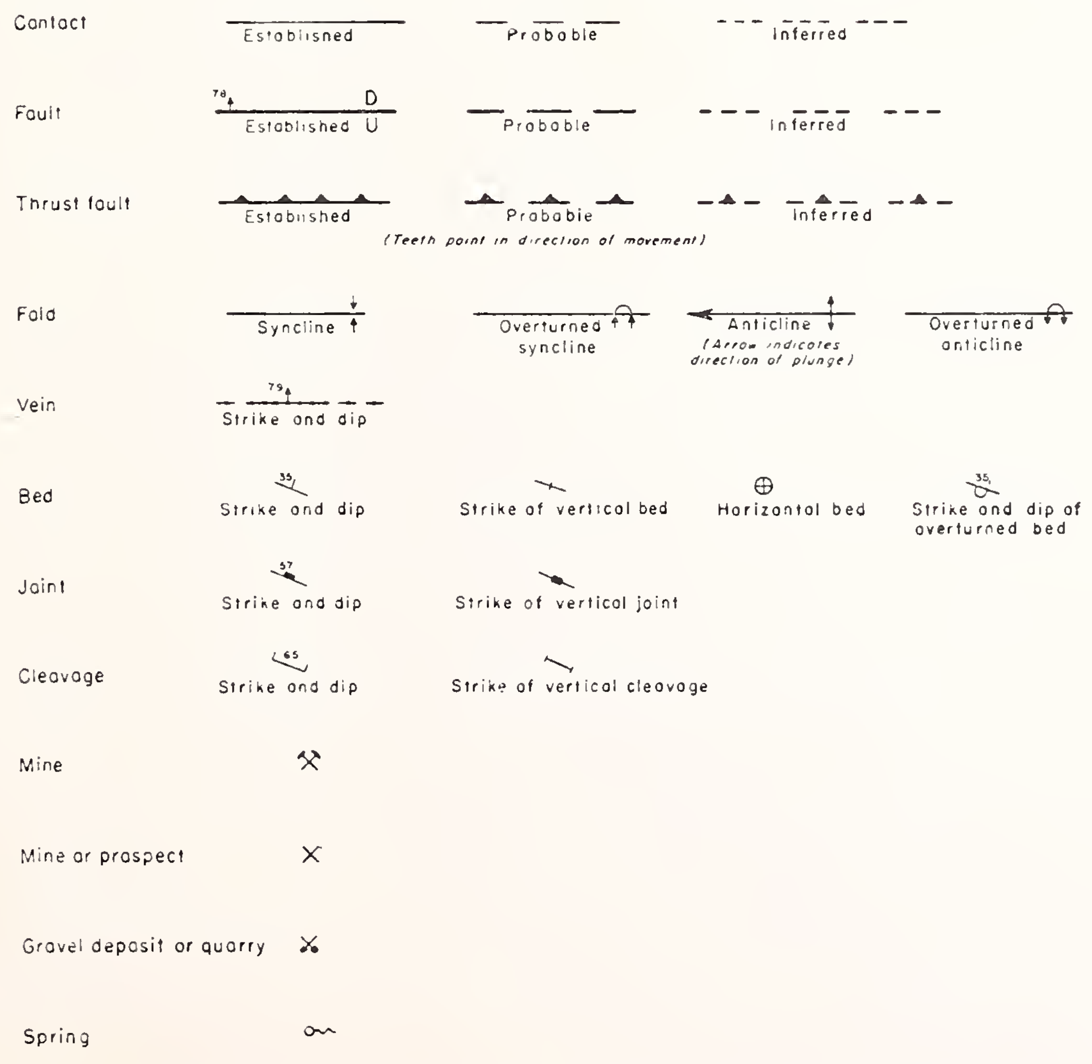


PLATE 11 — GEOLOGIC MAPS AND CROSS SECTION

CORRESPONDENCE

PACIFIC POWER & LIGHT COMPANY
920 S.W. SIXTH AVENUE · PORTLAND, OREGON 97204 · (503) 243-1122

Jack T. Stiles
Vice President

January 22, 1980

Mr. Sidney Knutson, P.E.
Seattle District, Corps of Engineers
P. O. Box C-3755
Seattle, WA 98124

Dear Mr. Knutson:

Your letter of November 21, 1979 transmitted to Mr. R. J. Kauzlarich copies of the final draft report on Flower Creek Dam inspection for review and comment. We are generally in agreement with the report, the findings and most of the conclusions. We believe the third sentence (If the original . . . this inspection) under Section 3.2b of the recommendations should be deleted. Reference No. 7 on Page 34 should read "Baker, F. G." and not "deSousa, S. A."

We appreciate the opportunity to review the report.

Very truly yours,

Jack T. Stiles

JTS/lh

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

THOMAS L. JUDGE, GOVERNOR
32 SOUTH EWING
STATE OF MONTANA
(406) 449-2872
HELENA, MONTANA 59601

January 17, 1980

Ralph Morrison
Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Dear Mr. Morrison:

The Department of Natural Resources and Conservation has reviewed the final draft report on the Flower Creek Dam Project near Libby. We concur with the findings and recommendations and feel the report is complete and satisfies the criteria for a Phase I evaluation. Minor editorial comments have been discussed with your staff and we understand they will be incorporated into the final report.

Thank you for this opportunity to review and comment on the final draft report for this project.

Sincerely,

Richard L. Bondy

Richard L. Bondy, P.E.
Chief, Engineering Bureau

RB:GM:mb

MORRISON-MAIERLE, INC.
QUALITY ASSURANCE
QA

Rodger C Foster
Project Manager

Branch Manager or Department Head

Peer Reviewer

Harold L. Engle
Principal-In-Charge

Chief Engineer No. 80-07	Date Approved 04 APRIL 80

Project No. 1447-05-01(33)